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## ANCIENT FINGER PRINTS IN CLAY

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WHERE men are and where men have been there occur various traces, or tracks. The traces to be considered here are of a single kind, impressions of the fingers[1] on things which have been handled or touched. A finger may leave its imprint as a transferred film of natural skin secretions or of some other medium with which the finger has been smeared, and if the digit is pressed into a plastic substance such as clay its impression is then in the form of a mould, shallow or deep in accord with variable conditions of imprinting. These moulds of human fingers are of special interest as traces, since in clay they may be preserved through the centuries. A few examples of ancient prints are presented, not only for their intrinsic interest but to provide the setting for discussion of a moot question in finger-print history, as to whether such prints in clay ever were made with an aim comparable to that of present-day identification.

Certain principles of identification method must be first introduced. For the registration of individuals, whether in criminal or non-criminal files, impressions of the digits are printed on cards, usually in ink. All ten digits are recorded in orderly series and with care to ensure that the details of the ridged skin are clearly and fully imprinted. Filed according to a classification of the finger-print patterns which admits ready reference, the card serves thereafter as a means of proving the identity of the individual, since the making and classifying of his prints at any future date will serve to locate that record for comparison. It is possible also to classify and file separately the prints of single digits, to facilitate identification of finger prints found at the scene of crime. All original record prints and all prints taken from the person for later comparison naturally are made purposefully, for identification.

The second technical variety of finger prints embraces those imprinted without intention, termed chance or accidental impressions. These may be either latent, formed of the skin secretions alone, invisible without special preparation or at best faintly visible, or they may be of ink, paint, blood and like materials clinging to the skin. Only infrequently does the identification worker have occasion to deal with chance impressions in plastic substances. It is important to emphasize that chance prints are made, as their name indicates, in the course of ordinary contacts with objects. The reader holds the book open that he may read, the murderer grasps the gun with evil purpose, the glazier presses putty around the window glass to obtain a firm and neat seal—but no one of these intends to be making the finger prints which he leaves in the act. Chance prints are all about us in myriads, though most of them are incon-

[1] The word "finger" is used throughout in the generic sense which embraces thumbs as well as the fingers proper.

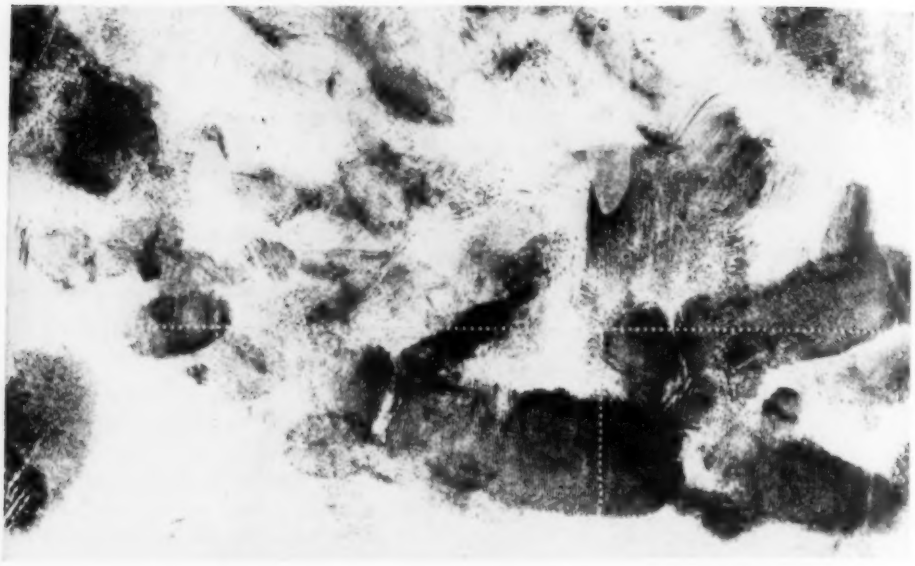

FIG. 1. LATENT PRINTS ON THE BACK OF A SHEET OF CHECKS*
DEVELOPED WITH SILVER NITRATE. THE SHEET, FROM A CHECK BOOK USED IN EXECUTING SEVERAL FORGERIES, HAD BEEN CARELESSLY HANDLED BY THE INVESTIGATORS. SUCH CHANCE IMPRESSIONS ON PAPER MAY BE LIKENED TO IMPRESSIONS PRODUCED IN THE HANDLING OF SOFT CLAY.

spicuous or invisible. If subjected to proper treatment, this page would reveal impressions, just as prints were developed on the sheet of checks illustrated in Fig. 1—an example which is not only a telling illustration of latent prints but a practical warning, in that investigators of a case of forgery carelessly handled these checks, obscuring a source of evidence with their own prints!

Having distinguished chance prints and those made intentionally for identification, it is to be emphasized that some impressions are identifiable, while some are not. To say that a print is identifiable does not mean necessarily that the identity of the maker can be disclosed, this being obviously impossible in the absence of some form of registration for reference; the point is simply that the print is technically adequate for comparison with another, to determine whether it is from the same digit or a different one. When prints are recorded for identification it is to be expected that they satisfy that purpose, but chance prints are often useless for comparison, since the markings of the skin ridges may be indecipherable or the available area lacking in sufficient details to establish identification. Ink prints, or developed latent prints, may be mere smudges or blobs, and prints in clay may be similarly devoid of ridge details, thus not being identifiable. We are to be concerned with both classes. In Fig. 2 there will be seen a complete and clear impression printed in ink, typical of the technique of identification records. The

* Fig. 1 is being used by courtesy of M. Edwin O'Neill and the *Journal of Criminal Law and Criminology*. Fig. 3 is from Badè, by courtesy of the Palestine Institute of the Pacific School of Religion. Fig. 4 is from Laufer, by courtesy of the Field Museum of Natural History. Fig. 5 is by courtesy of Professor A. D. Fraser. Fig. 6 is from B. C. Bridges and Fig. 7 from Earl H. Morris. Fig. 8 is by courtesy of the Middle American Research Institute, Tulane University. Photograph by Roy Trahan.

imprinted lines, which represent the summits of the delicate skin ridges, exhibit numerous "minutiae"—forkings, endings and abbreviations in length. Even a portion of such a print is identifiable when it contains a sufficient number of ridge details, individually distinctive as they are. The companion illustration is a blob, utterly useless for identification. With regard to prints in clay, it may be noted that occasionally (as in Figs. 3, 4, 5) they are identifiable, while others (Fig. 6) are featureless excavations in the clay, corresponding in their lack of individual markings to the blob made with ink.

Its documented history dating only from the latter part of the nineteenth century, the present finger-print system may have originated quite independently of finger-print practices followed long ago in the East. The history of these practices has been pieced through the efforts, among others, of the late Berthold Laufer, in his "History of the Finger-print System,"[2] of Robert Heindl, in the historical sections of "System und Praxis der Daktyloskopie,"[3] the most comprehensive handbook in its field, and of George Wilton, in the recent work, "Fingerprints: History, Law and Romance."[4] Their accounts contain descriptions of numerous instances of finger marks applied to deeds, contracts of loan and other documents; one example will suffice to illustrate the characteristic employment of these marks.

Wilton cites a Chinese contract of loan executed nearly twelve hundred years ago, bearing the prints of witnesses as well as those of the parties to the contract. Appended to the contract there is the formula: "The two parties have found this just and clear, and have affixed the impressions of their fingers . . ."; it concludes, still according to the Chavannes translation of the Chinese, "pour servir de marque." Assuming that Chavannes is correct in his translation, it appears that "pour servir de marque" must have meant only "to serve as a mark [token, or sign]," and that the sense of distinctiveness in Laufer's (1917) rendering of this phrase from the French ("to serve as a *distinctive mark*") is gratuitously introduced.

Wilton, who examined the document which bears the prints, remarks:

> Dr. Giles states that he is of the opinion that the fingermarks shown upon it are blobs and of no use for identification purposes. . . . To the eye of a layman, the fingermarks . . . do resemble blobs. With the magnifying glass, it is difficult to discern finger-ridge lineations. The marks seem to have been made more by the tips than by the bulbs or pads of the fingers. I do not think, however, that it would be reasonable to infer from the examination of this particular document that all fingermarks upon writings of the period in question were so blobbed as to make identification impossible.

Certainly Wilton is justified in insisting against any inference that prints made at that time were invariably mere blobs. Some examples, indeed, long antedating the inauguration of the finger-print system as we know it, are identifiable prints. It would be fallacious to assert positively that a print was not made for identification because it is a mere blob; while their occurrence is

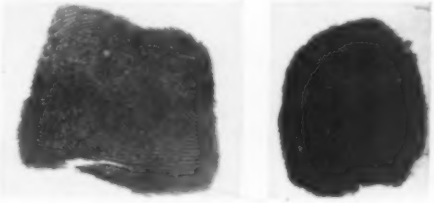

FIG. 2. FINGERPRINT COMPARISON
A CLEAR PRINT, MADE IN INK, SHOWING RIDGE DETAILS, AND AN UNIDENTIFIABLE BLOB.

[2] Smithsonian Inst., Annual Report, 1912, pp. 631–652. This was followed up in a brief note by Laufer, *Science*, n.s., 45: 504–505, May 25, 1917.

[3] Berlin and Leipzig: Walter de Gruyter and Company, 3rd ed., 1927.

[4] London, Edinburgh and Glasgow: William Hodge and Company, Ltd., 1938.

FIG. 3. ON PALESTINIAN LAMP

A CLEAR IDENTIFIABLE PRINT ON A FRAGMENT OF A MOULDED PALESTINIAN LAMP (BYZANTINE PERIOD, THE FOURTH OR FIFTH CENTURY A.D.).

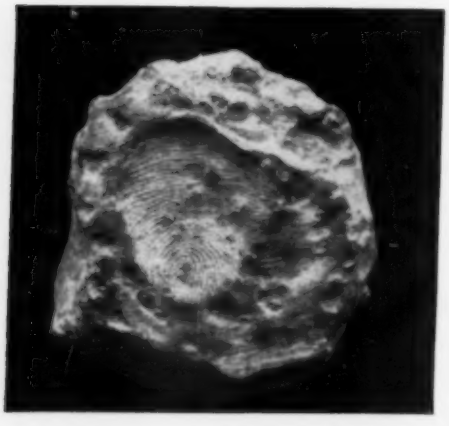

FIG. 4. A CHINESE SEAL OF CLAY

MADE NOT LATER THAN THE THIRD CENTURY B.C. THE OBVERSE SIDE OF THIS CLAY PAT BEARS A SEAL-IMPRESSED NAME, PRESUMABLY THAT OF THE MAKER. WAS THE THUMB PRINT APPLIED AS AN IDENTIFYING MARK IN THE CURRENT SENSE OF FINGER-PRINT IDENTIFICATION?

exceptional, blobs are not unknown even to-day in official files.[5] It must be admitted that even if ancient records do bear an overwhelming majority of blobs, rather than clear prints, the frequency of the fault is not a final argument for lack of intention to make identifiable prints. Borrowers and lenders thus signed their notes, buyers and sellers applied prints to deeds, and in these and other transactions the prints of witnesses sometimes were added. If there were a finger-print science in their times expertness in its methods hardly could have been a qualification of many signers, busily occupied with other affairs! Even now there are persons who have the notion that any finger mark, however blurred, is fit for identification, and the product of their finger-printing might be no better.[5] On the other hand, it does not follow that the presence of clear details such as are found occasionally on other ancient documents, in China and elsewhere, is in itself evidence that the prints were made for true finger-print identification. Both clear prints and blobs alike may have established, in some instances at least, only what may be designated a "token identification."

Prints in old clay ware figured in the history of modern identification methods, to the extent that one of the pioneers of finger-print science was led to his investigations through an interest first stimulated by observing them. In 1880 Henry Faulds (1843–1930), a Scottish medical missionary then stationed in Japan, addressed a letter to the editor of *Nature*.[6] Among other matters of less immediate practical bearing, this letter directed attention to the usefulness of prints for

[5] For example, M. Edwin O'Neill (*Jour. Crim. Law and Criminol.*, 30: 929–940) reproduces the thumb prints accompanying the medical examination of a sailor in the Merchant Marine. The prints are solid blobs of ink which, like that shown here in Fig. 2, would be utterly valueless for identification.

[6] *Nature*, 22: 605, October 28, 1880.

personal identification, and in it Faulds related the genesis of his interest in finger impressions:

> In looking over some specimens of "prehistoric" pottery found in Japan, I was led, about a year ago, to give some attention to the character of certain fingermarks which had been made on them while the clay was still soft. Unfortunately, all of those which happened to come into my possession were too vague and ill-defined to be of much use, but a comparison of such finger-tip impressions made in recent pottery led me to observe the characters of the skin-furrows in human fingers generally.

FIG. 5. FRAGMENTS OF TWO FIGURINES FROM SELEUCIA, MESOPOTAMIA
THE IMPRESSIONS ARE ON THE INNER FACES OF THE FIGURINES, THEIR SUCCESSIONS SUGGESTING THE MOST NATURAL AND EFFECTIVE WAY OF APPLYING THE SOFT CLAY WITHIN A MOULD OF IRREGULAR FORM. ENLARGED ONE AND TWO-THIRDS TIMES.

Anticipating the dealing with individual examples of finger prints on ancient clay seals and tablets, pottery, figurines and bricks, a preview of the possible explanations of their occurrence may be helpful. (1) It must be granted, as Laufer has pointed out, that there was recognition of the individual variability of finger-print characteristics before the inception of the modern identification system in the latter part of the nineteenth century. It is possible, therefore, that imprints on plastics may have been applied in some instances to serve for personal identification in the current sense, though definite evidence supporting this possibility would be difficult to produce. For the sake of brevity, the present-day method will be termed *finger-print identification;* finger prints made purposefully for identification according to its conventions will be designated *identifying prints.* (2) The symbolic associations of the fingers (and hands) appear to have been the motivation of at least some of the ancient recordings of finger marks, and some imprints in clay doubtless were of that import. The sense of "identification" is here quite different from that of finger-print identification. The primary in-

tent of such imprints would be simply to register *marks made by the person*, establishing the "sympathetic relation" as it is termed by Laufer, and if they proved occasionally to be identifiable prints that result was fortuitous. The finger prints, identifiable or blobbed, which served the purpose may be called *token finger marks*, and the "identification" afforded by them a *token identification*. (3) Since fingers are ever-ready tools it would not be surprising if they were used in certain instances for the making of recognition marks on plastic objects. Variable placings and different numbers of fingers plunged into the still soft clay of bricks, pots and other objects would make it possible to identify the makers or to designate other sortings of the products. Such marks will be distinguished as *finger signs*. But it should be apparent that finger signs are by no means comparable to the identifying prints of finger-print identification. Their purpose would have been accomplished as well if sticks instead of fingers had been employed for marking, unless there were involved as well some element of token identification. (4) Finally, considering that plastic clay has been worked into form by the fingers, it must be evident that a share of the prints preserved in the finished objects are chance impressions of these natural tools. Let us call them *chance prints*, signifying that as prints they were not applied purposefully, notwithstanding purpose in the act of grasping or modeling the soft clay.

In connection with finger prints in clay Laufer states:

> Finger marks may naturally arise anywhere where potters handle bricks or jars, but every expert in finger prints will agree with me that these are so superficial as to render them useless for identification. A clear and useful impression in clay presupposes a willful and energetic action, while the potter touches the clay but slightly. However this may be, we are not willing to admit as evidence for a finger-print system any finger marks of whatever kind occurring in pottery of any part of the world, unless strict proof can be furnished that such marks have actually served for the purpose of identification.

Laufer's general position on the evidential status of prints in pottery offers no ground for disagreement, but he is mistaken in the belief that chance prints on pottery are invariably useless for identification, as will be shown by example. And he is mistaken also in his analysis of the mechanical factors involved in the production of clear prints. On the basis of experiments with clay and other plastics, and by observation of imprints in pottery, the writer holds that so long as the imprinting finger is applied without dragging which would blur the print, the important factors determining clearness of the print are the texture and consistency of the clay. A coarse-textured clay will not yield prints which are identifiable, nor can even a fine clay if it is either of very thin consistency or too firm. Attention may be recalled, finally, to the two connotations of the word *identification*. The "strict proof" demanded by Laufer, "that such marks have actually served for the purpose of identification," is not lacking if we broaden the sense of the word to include token identification. Some ancient prints on clay, like those on the Chinese documents and the clay seal mentioned below, are pedigreed associations with particular persons, recorded with the object of "identifying" those persons with their contractual obligations. "Identification" of this sort bears a close relationship to the signing of a document by an illiterate. Neither a finger-print blob nor the illiterate's cross mark possesses qualities by which identification can be established objectively, yet each carries weight as a sign of bodily action of the individual. Finger-print identification is entirely objective, quite unrelated to the aims and procedures of the token identification

FIG. 6. AZTEC FIGURES, SHOWING DEPRESSIONS IMPRESSED BY DIGITS ON THE REVERSE SURFACE (ENLARGED ONE AND ONE THIRD TIMES).

effected by applying any sort of finger mark.

Among the clay objects which are of interest in connection with finger-print history are Chinese seals. Laufer presents an extensive discussion of such seals, and from his account the following information is taken. Prior to about the first century B.C. clay seals were used extensively in sealing documents, written at that period on slips of bamboo or wood, official letters and packages. Some among the several specimens specially described by Laufer were moulded around fingers, and there is one, thought to have been made not later than the third century B.C., bearing a firm, clear thumb print (Fig. 4). Laufer points out that the application of such a print and the manipulations of other examples indicate that "the primary and essential point in these clay seals was a certain sympathetic relation to the fingers of the owner of the seal." He continues:

> Here we must call to mind that the seal in its origin was the outcome of magical ideas, and that, according to Chinese notions, it is the pledge for a person's good faith; indeed, the word *yin*, "seal," is explained by the word *sin*, "faith." The man attesting a document sacrificed figuratively part of his body under his oath that the statements made by him were true, or that the promise of a certain obligation would be kept. The seal assumed the shape of a bodily member; indeed, it was immediately copied from it and imbued with the flesh and blood of the owner.

This thumb-print specimen, of all the imprints in clay known to me, is the only instance which seems entitled to serious consideration as a possible *identifying print*. Its importance is therefore such that Laufer's interpretation should be stated in his own words:

> It is out of the question that this imprint is due to a mere accident caused by the handling of the clay piece, for in that case we should see only faint and imperfect traces of the finger marks, quite insufficient for the purpose of identification. This impression, however, is deep and sunk into the surface of the clay seal and beyond any doubt was effected with intentional energy and determination. Besides this technical proof there is the inward evidence of the presence of a seal bearing the name of the owner in an archaic form of characters on the opposite side. This seal, 1 centimeter wide and 1.2 centimeters long, countersunk 4 millimeters below the surface, is exactly opposite the thumb mark, a fact clearly pointing to the intimate affiliation between the two. In reasoning the case out logically, there is no other significance possible than that the thumb print belongs to the owner of the seal who has his name on the obverse and his identification mark on the reverse, the latter evidently serving for the purpose of establishing the identity of the seal. This case, therefore, is somewhat analogous to the modern practice of affixing on title deeds the thumb print to the signature, the one being verified by the other. This unique specimen is the oldest document so far on record relating to the history of the finger-print system.

Not all these views withstand close examination. It is probable that the maker of the clay tablet was the person whose thumb print and seal it bears, though it is not impossible that two persons executing a contract might have cooperated in making the seal, the one impressing his name and the other his thumb. There is no reason to doubt that the thumb was impressed intentionally. Except in the area of the thumb print, the reverse face is rough, showing no evidence of having been surfaced with fingers or a tool. While this state might be regarded as an indication of purposeful recording of the print, neither it nor the quality of the print denotes unquestionably the designed recording of an identifiable signature. The possibility exists, of course, but there is nothing to support the interpretation that this particular impression is more meaningful as an evidence of early finger-print identification than are the other seals, and much to say against it, including Laufer's own statements on the symbolic significance of seals generally.

Fingers were sometimes impressed in ancient bricks of various localities, as in those from the storehouse of the first

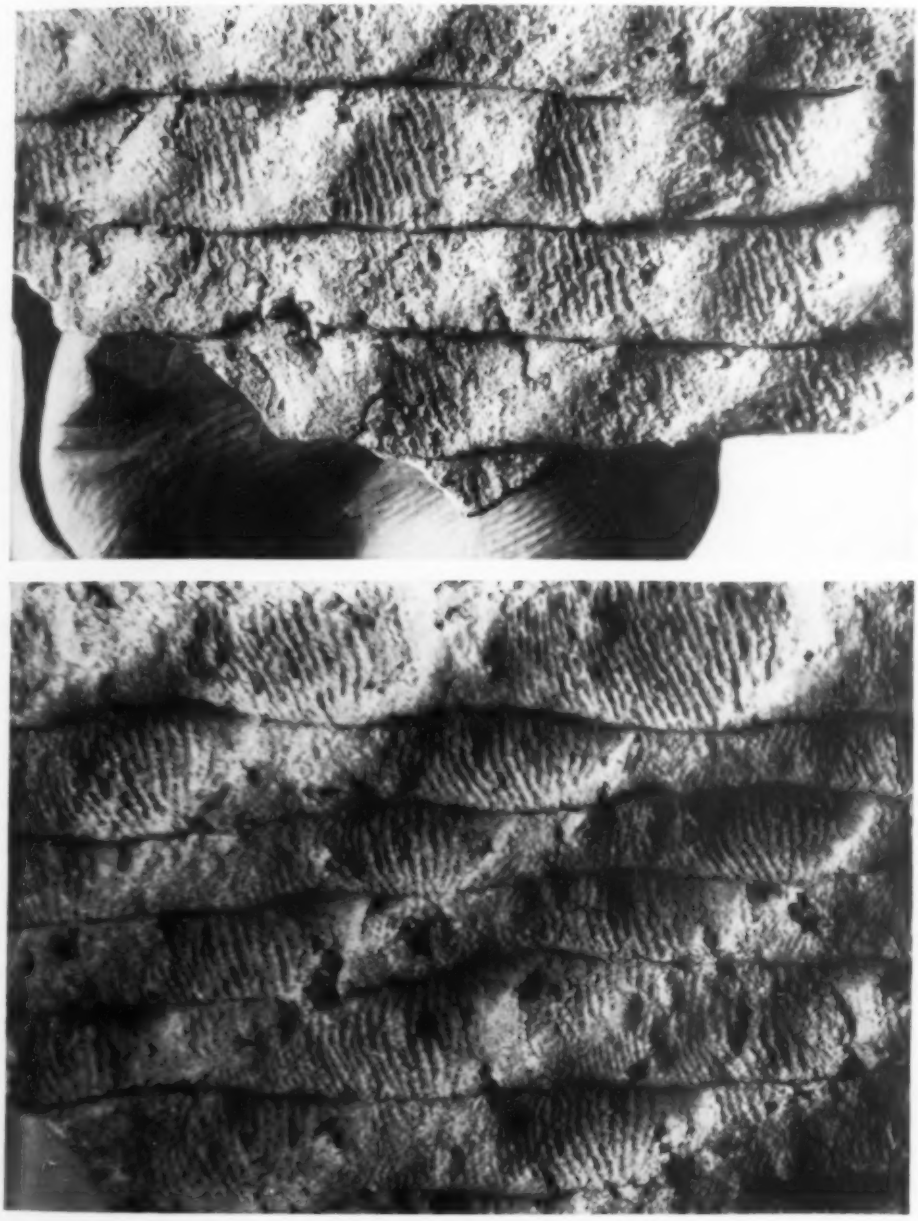

FIG. 7. SHERDS OF INDENTED CORRUGATED POTS, ENLARGED FROM THE LAPLATA VALLEY OF NEW MEXICO (EARLY PUEBLO III PERIOD, 900–1100 A.D.). THE THUMB IMPRESSIONS RESULT FROM USE OF THE DIGIT AS AN INDENTING TOOL.

king of the Lagash dynasty in Mesopotamia, dating from about 3000 B.C. These bricks are described by Handcock[7] as being plano-convex in shape, each bearing a digital impression on the convex face. Maspero,[8] in a general characterization of Egyptian bricks, states: "Bricks from the royal brickyards are occasionally stamped with the cartouche of the reigning sovereign, those from private factories are marked with one or more conventional signs in red ink, a print of the moulder's finger or the maker's stamp. The greater number have no mark." Birch[9] describes the unburnt bricks of the Southern pyramid at Dashour as mostly having been made of "rubbish, containing broken red pottery and pieces of stone." He asserts that: "The kinds were distinguished by *various marks made by the finger* [italics mine] on the brick before it was dry. In one instance this seems to have been effected by closing the fingers and dipping their points into the clay." Birch describes also Chaldean bricks, bearing "impressions of the five fingers, or of a circle, probably the brickmaker's private marks." Some writers on the history of finger-print science have cited these marks on bricks as evidence of early employment of finger prints for identification. Aside from the fact that rough materials used in brickmaking preclude identifiability of the prints, it is apparent that if the marks served as recognition signs their serviceability must have been on an entirely different basis from that of finger-print identification.

The Assyrian clay tablets on which were recorded in cuneiform symbols the terms of contracts, deeds and similar agreements bear "signatures" both in the form of personal seals and digital impressions (Maspero).[10] The fact that at least some of the impressions are but indents of the finger nails seems to point to their nature as token identifications.

The late William Frederic Badè, as director of the Palestine Institute of Archaeology, conducted at Tell en-Nasbeh excavations which have led to the identification of the area as the site of Benjaminite Mizpah, the capital of Judah after Jerusalem was destroyed by the Babylonians, 586 B.C. The excavations are exemplars of systematic method in the removal and careful indexing of enormous quantities of artifacts, of which pottery fragments represent a large share. Many of these fragments bear identifiable finger prints, on handles at the extremities where they had been attached to vessels and on the inside surfaces of moulded lamps, the latter being the more nearly perfect impressions. One print, here copied in Fig. 3, has been used by Badè as the frontispiece of his book, "A Manual of Excavation in the Near East,"[11] where its laconic label, "Finger print of a potter," tells all that can be said as to the identity of the man, only that it was he who moulded the ware. But repetitions of the prints on many different pieces tell further that it was this same forgotten potter who made them all—a finding which has been put to use in dating the origin of confused débris.

In discussing the prints found by Badè, Bridges[12] expresses his judgment that "these impressions were obviously intentional and, no doubt, represented the workman's individual trade-mark." The implication of the context is that the trade-mark would have been identi-

[7] "Mesopotamian Archaeology." New York: G. P. Putnam's Sons, 1926.

[8] "Manual of Egyptian Archaeology." New York: G. P. Putnam's Sons, 1926.

[9] "History of Ancient Pottery." London: John Murray, 1873.

[10] "Life in Ancient Egypt and Assyria." New York: D. Appleton and Company, 1899.

[11] University of California Press, 1934. (Badè's work is reviewed by an anonymous writer in *The Scientific American*, vol. 152, 1935.)

[12] *Finger Print Magazine*, 18: 11, 1937.

fiable as a finger print, though Badè has been quoted elsewhere[13] as saying: "I do not for a moment believe that the potters were aware that their finger prints had the distinctiveness which is now recognized in the finger-print system. It is the place and arrangement of the impressions which served as distinguishing marks to them." This view throws quite a different light on the significance of the prints in question; if serving as "trade-marks," it was not as finger prints *per se* that they proved useful, for if only their placing and arrangement supplied the identifying signs scratches or other markings could have served as well. It is not open to proof, of course, that the prints were impressed for this purpose. Regularity of their positions in the output of a particular potter, which is suggested in Badè's comment, might signify nothing more than regularity of habit in the manipulations of potting. In attaching a handle the potter must needs have impressed a thumb or finger in joining it and the vessel with a firm bond. His intention certainly was to join them, but the imprint was a by-product of the process. Likewise in moulding a lamp or other vessel, the intention was to determine a particular form, and prints would have been impressed in the contact.

In a study of the technology of Pecos wares,[14] products of our own prehistoric Southwest, Miss Anna O. Shepard deals with many different types, of which one is of present interest. In the construction of this type, coiled pottery, clay is manipulated into a thin roll which is coiled and welded in a continuous wall. The marks incident to this method of manufacture are effaced in the making of a smooth-finished vessel, but they may be retained, the successive coils then showing as horizontal corrugations or ribs on the surface. In the process of coiling decorative indentions may be added, these being depressions spaced at regular intervals on the coil, made with either a digit or tool. The pottery to which I shall refer is both corrugated and indented, the indentions having been made by the edge of the thumb. Two sherds are illustrated in Fig. 7. The one uppermost in the figure is of peculiar interest, not that the sherd is more noteworthy than the other but because of an accessory feature of the illustration. The photographer, quite unaware that his technique would make the picture the more useful in this discussion, had posed the sherd by pressing it against a lump of plasticine or similar material. The mass had been kneaded into convenient form to serve as a support, and as will be noted even in the lack of sharp focus at this deeper level, the plasticine bears clear impressions of the skin features of the photographer's hand. Being chance impressions, made in the process of an operation designed for another purpose than to produce the prints, they are exactly analogous to the more durable prints in the accompanying piece of pottery.

In keeping with her thoroughgoing attack in other particulars of ceramic technology, Miss Shepard has investigated these imprints with care, and she finds that they throw light on the operations of pottery-making. The directions of the lines impressed by the skin ridges at the edge of the digit admit reconstruction of the method by which the coil was welded and indented. This finding, significant as it is in historical ceramic technology, is not related to the aim in citing the corrugated indented pottery. Of interest at the moment is the bearing of the thumb impressions on questions of finger-print history. Small as they are, and though they represent the margin of the thumb rather than the ball

[13] *Science News Letter*, October 27, 1934.

[14] Pottery of Pecos (A. V. Kidder). Papers of the Southwestern Expedition, No. 7, Vol. 2, Part 2. Yale University Press, published for Phillips Academy, 1936.

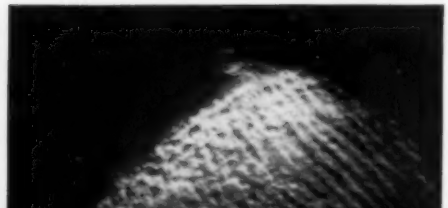

FIG. 8. IMPRINT ON CLAY HEAD
A CLEAR IMPRINT ON THE REVERSE SURFACE OF AN ANCIENT CLAY HEAD (MEXICO). THE FIGURE HAD BEEN MOULDED IN TWO PIECES, AND THE IMPRINT WAS CLEARLY MADE IN THE PROCESS OF JOINING THEM. ENLARGED FOUR TIMES.

where the pattern is located, the areas of impression in some examples show a few ridge details, which naturally are repeated time after time in the imprints of the digit. While the limited number of ridge details would not justify a positive identification under the ordinary conditions, their repeated occurrence on prints of the same sherd is itself strong evidence that they were made by one potter! The prints thus are identifiable, with reservations, but they were not made for identification. They were impressed in a potting method which makes use of the thumb as a tool. They are the exact equivalent, in origin, to impressions found, for example, on the edges of some old Roman pieces. Digits were employed in the making of scalloped borders, the finger prints resulting as the scallops were shaped. They are chance prints, no more significant from the standpoint of finger prints recorded for identification than are the short-lived impressions left by the cook in crimping the edge of a pie.

In an account dealing with small clay figures of Aztec manufacture, recently excavated in southern Texas, B. C. Bridges[15] considers that the impressions of fingers present on some of them may have been made as identifying marks, though he adds the qualifying reservation that it was "sometimes through accident," as well as "often by design, [that] the maker must have left upon these earthen forms the trademark of his finger prints." Of the seven specimens illustrated in his article, three bear finger impressions. Through his kindness I have received copies of the original photographs, from which two examples have been selected for reproduction (Fig. 6). Both are heads, and each shows on its reverse surface the mould of a digit. I have examined a large series of similar figures, in the Middle American Research Institute at Tulane University and elsewhere. Frequently the reverse surfaces of the objects bear excavations which clearly are impressions of fingers. But their occurrence, whether on heads of the type cast in clay moulds or on hand-modeled figures, leads only to the conclusion that the imprints are to be explained simply as chance marks of manufacture. At least some of the figures were cast in moulds, and the manufacturing significance of the indent of a thumb or finger is readily apparent. In so casting a small head the most natural procedure would be to use a digit in pressing the soft clay into the mould. In many specimens the finger imprints lack signs of the skin ridges, as if rubbing had effaced them or the clay were not of optimum consistency and texture to register these details.

[15] *Finger Print Magazine*, 20: 8, 1939.

One head which shows details was constructed in two pieces—the head proper and head-dress being joined after modeling. The details of the skin markings, reproduced in Fig. 8, are fairly clear. The imprint, far from having an identifying or symbolic connotation, is so placed on the back of the figure that its origin as a chance imprint produced in the joining of the two pieces is indisputable, as are those observed on a Toltec figurine, obviously associated with the joinings to the torso of the separately modeled head, arms and legs.

Through the kindness of Professor A. D. Fraser, of the division of archaeology at the University of Virginia, I am permitted to refer to an excerpt from an unpublished manuscript and to reproduce two photographs of finger prints impressed in clay. He writes:

> But occasionally the potter may impress his fingers in the clay after the wheel's revolutions have ceased; or he may jab a finger down hard against the interior of the aryballos for the purpose of flattening the exterior surface of the bottom, and thus supply us with the desired impression. . . . In the firing of Roman *terra sigillata*, the bowls were usually stacked one within the other and were supported on the finger-tips of the workman as they were placed in the kiln. As a result their under surfaces bear numerous prints; but these, owing to the condition of the glaze, as has been explained above, are in almost all cases mere smudges. But occasionally one is seen whose pattern is reasonably distinct. Our richest field for the study of dactyloscopy amid ancient ceramic products is found undoubtedly in the interior of figurines and lamps. As the figurine is the product of the hand of the coroplast, or of the hand aided by small modelling tools, the print-smearing wheel is not in evidence. The same thing is partly true of the ancient lamp and the plastic vase. . . . Frequently we find well-defined prints in their interiors. . . .

Two of Professor Fraser's specimens, of Mesopotamian origin, are shown in Fig. 5. The photographs represent interior surfaces of fragments of figurines, each showing the "inching along" of the potter's fingers as he pressed the soft clay into a mould. Again these finger prints are obviously nothing more than tool marks. Wilhelmina van Ingen,[16] in discussing similar figurines from the same locality, makes specific references to prints occurring on individually described examples and adds the following general comment on the method of manufacture.

> In the simplest of the mouldmade figurines the wet clay was pressed into a single mould, which gave the impression of one side of the figure only, usually the front. . . . The back was either roughly shaped by hand to be concave or convex, in which the maker's fingerprints are visible, or pared with an instrument.—In this process [the use of a double mould] separate moulds were used for the front and back halves of the figurine. The clay was pressed into each half of the mould, sometimes in several layers, to make a hollow shell (the fingerprints are always very clear).

There is no need to multiply instances further, describing more objects made of clay and extending the provenience in geography and time of those which carry finger impressions.[17] If not effaced by a finishing process or otherwise, imprints are to be found wherever plastic clay of suitable consistency and texture has been handled. In considering ancient examples there is danger of reading in

[16] "Figurines from Seleucia on the Tigris." Ann Arbor and London: University of Michigan Press and Oxford University Press, 1939.

[17] Among the examples recorded in the literature, additional to those mentioned in the text, the following may be noted: (1) Chance prints on bases of old Roman columns probably dating from the third century, A.D.—Sir William Turner. *Jour. Anthrop. Inst. Great Britain and Ireland*, vol. 30, new series, III, pp. 106–107, 1900. (2) Chance prints on a small vase of the neolithic period.—B. Males and M. Grbic. *Riv. d. Antrop.*, vol. 29, pp. 603–606, 1930–32. (3) Deep end-on excavations made by the finger tips, as by a dibble in soil, in the internal surfaces of Lake-dweller pots of the Bronze Age; from several to as many as 70 such pits occur in a single vessel; their purpose is problematic, but one of the suggestions advanced is the increase of heating area of the bottoms of pots used in cooking. Meisner [with important discussion by Kollmann], *Arch. f. Anthrop.*, vol. 27, pp. 120–122, 1900–1902.

them meanings which do not actually exist. While the historical uncertainties associated with their age offer a tempting ground for speculation, the availability of parallels in modern ceramics stands as a constant warning that too much license must not be allowed in interpreting such finger impressions. In my possession there are, for example, a tall Holland gin bottle with finger impressions so placed as to show that it was grasped and lifted before the plastic material had set, a clay jug with similar markings, a pottery cup having a finger-crimped border bearing a succession of prints, and two small moulded teapots which are literally covered with impressions of the fingers which formed them. In these there is not the slightest reason to believe that the finger prints were applied as identifying marks in any sense. If all the prints on old pottery are not to be explained on a like technological basis, and many of the recorded objects are best thus interpreted, it does not follow necessarily that intentional impressions of the fingers were made for the kind of identification which is practiced to-day. The intentional impressions fall into two classes: (1) merely symbolic personal marks, serving a token identification; (2) marks made for recognition, by spacing or number, as a tool might be used for that purpose. Finger-print identification in our usage of the term appears to have been practiced in a simple form in times long past, but some briefs for its claim to great age embody "evidences" which do not bear close scrutiny. The history of finger-print identification becomes shadowy as it is traced backward, and occasionally shadows of the remote past have been forced into standing for substance.

## SCIENCE IN PEACE AND WAR

THERE is indeed a widespread recognition of the general effectiveness of science. The ways of using science and scientific men are being slowly discovered. But the process is slow. It would, I think, be hastened, if certain fundamental truths were generally known and recognized. I venture to state them in the form of a few propositions:

1. Science, that is to say, the knowledge of nature, is of fundamental importance to the successful prosecution of any enterprise.

For example, a nation is obliged to make all possible use of science in preparation for war, whether aggressive or defensive: and, again by way of example, in the maintenance of public health and social welfare. Of course, science is not alone in being a necessity in either case.

2. Science is of general application. There are not one science of chemistry, another of electricity, another of medicine and so on: there are not even distinct sciences of peace and war. There is only one natural world, and there is only one knowledge of it.

Experience shows that an advance in knowledge or technique or skill in any direction may be based on some item of knowledge acquired in a far distant field of research. For that reason, it is necessary to resist strongly a natural tendency for those who study science or apply it, to separate into groups without mutual communication.

3. Fruitful inventions are always due to a combination of knowledge and of experience on spot. Unless the man with knowledge is present at the place and the time when some experience reveals the problem to be solved he misses the fertilizing suggestion. Neither can the mastering idea suggest itself to the man who has the experience only but no knowledge by which to read the lesson that the experience teaches. The man with knowledge may be a temporary or special introduction, or, much better, he may be the man who meets with the experience.

4. There are difficulties peculiar to the application of science to war purposes. While the war proceeds scientists as a body are anxious to put all their knowledge at the service of their country: but when the time comes they are anxious to get away to their work on pure science or the applications of science to the problems of peace. Government may preserve and most fortunately has preserved a nucleus of able scientific effort during the last 20 years of peace, so that a certain connection is maintained between these particular applications and the general body of science, but from the very nature of their respective occupations, and on account of a certain secrecy which one of the two bodies is forced to maintain, the connection is not always strong. It can easily happen that the solution of a particular difficulty in the war service may lie in some piece of knowledge far away from the immediate science of the enterprise and unknown to those who need it.—*Sir William Bragg in his anniversary address before the Royal Society of London.*

# LAND TENURE IN TUNISIA

## INTER- AND INTRA-NATIONAL IMPLICATIONS

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> Where soil is, men grow,
> Whether to weeds or flowers.
> —*Keats, "Endymion."*

EVEN before the outbreak of the present war, France has persistently tried to "appease" Italy, in order, primarily, to have one less frontier to defend. Since the actual declaration of hostilities, Italy's leader has seemed to be too busy just keeping his country out of war to make demands on either Germany or the Allies. But this does not mean that Mussolini has given up all ideas of expansion in Mare Nostrum. Italian claims are only temporarily dormant. If it became apparent that Italian aid were necessary to the Allies for them to win the war a price would certainly be placed on such aid. And part of the price demanded by Italy would undoubtedly be that France relinquish Tunisia. Has Italy's "protective" instinct become aroused, or is the "Lebensraum" argument used in advancing this claim? A study of land tenure in Tunisia against its background of history and power politics may be revealing.

In April, 1880, the great estate of the Enfida, which comprised some 250,000 acres in the Sahel between Tunis and Sousse and belonged to the General Khayr-ed-din, was sold to a Marseilles Company for 2,000,000 francs. The bey of Tunis objected to the French that the estate had been given to the general for his own use, but that it could not be transferred to foreigners. The sale was held up by Yousef Levy, a naturalized English Jew, who claimed that he owned a plot of land bordering upon the Enfida, and demanded his legal right (chefâa), as an owner of adjoining property, to purchase the estate. England, who had till then given France a free hand, suddenly blew cold and sent battleships to Tunis to fight the French on this issue. The French allowed Levy to remain in control rather than fight England, but they bought his "rights" in 1882. Even before this was done France had beaten Italy to the draw. On March 30, 1881, several hundred Khroumirs in pursuit of tribal enemies in Algerian territory killed a few Frenchmen in an engagement with French troops. This was nothing new—border raids had been of almost daily occurrence for a decade. However, even if it was but a monotonous repetition of border forays, it was the necessary "incident." French troops occupied Tunis, and the bey had to sign the treaty of Bardo on May 12, 1881. Thus the climax in the last act in the drama of creating the French Protectorate over Tunisia was the sale of land to non-Moslems.

### SYSTEMS OF LAND TENURE

According to Moslem law land is theoretically considered not to belong to any one. It belongs to God, whose representative on earth is the temporal ruler, who thus has the sole right to all "dead lands," *i.e.*, those which have not yet been "brought to life" by man. Once man has started to cultivate the land he may claim himself owner, and his private property is known as a "melk." Both custom and Koranic law recognize private property, the essential element of which is possession. Proof of possession, according to Koranic law, consisted in showing that one actually occupied the

VINEYARDS NORTH OF TUNIS

WITH THE PICTURESQUE NATIVE TOWN OF SIDI BOU-SAID IN THE BACKGROUND. SIXTY PER CENT. OF THIS LAND IS OWNED BY ITALIANS WHO HAVE DEVELOPED THEIR SMALL PLOTS PURCHASED FROM THE GREAT ESTATES OF FRENCHMEN.

land and used and enjoyed the fruits thereof. But since this right was a religious one, only Moslems could acquire title to real estate. It was only in 1857 that Mohammed Bey, "urged" by the French and British consuls and influenced by his minister, General Khereddine, promulgated the "Fundamental pact," which among other things extended the right to private property to all inhabitants of Tunisia, whatever their race, nationality or religion.

In any agricultural country such as Tunisia the question of land tenure is of fundamental importance. The system was of course not a simple one because of Moslem law and concepts of property, but geographic and historic factors added to the complications: for instance, the Bedouins of the steppes and the desert did not have the same concepts of ownership as the sedentary populations of the north. Furthermore, the local leaders in many instances had by their arbitrary actions further complicated situations that already seemed tangled beyond hope.

When the French entered Tunisia they found that among the populations in the densely settled areas of the northeast, of the Sahel and of the oases the concept of private property, or melk, was already deeply rooted. French law could here be readily applied, but in many cases the title to the land was not absolutely clear and it was necessary to secure the owners in their right. According to the law of July 1, 1885, each property owner could demand the registration of his property. An inquest into the papers, deeds, wills or other papers was held before a specially selected tribunal, and if the verdict of this body was to the effect that the papers were valid the title could be duly recorded in the "conservation fonciere." The title was then con-

sidered to be a clear one, and a new deed was given the owner. From 1885 to 1928 titles to some 1,300,000 hectares of land were thus cleared. But this is a relatively small amount when compared to perhaps 9,000,000 hectares of arable land in the Protectorate.

Acting on the Moslem principle that the land belongs to the sovereign, many beys had acquired large estates or had allowed their henchmen to acquire them. Since it was felt that these "crown-lands," so to speak, were the logical areas for colonization they were placed under the administration of the Department of Agriculture of the Protectorate. Thus it was hoped that there would be an opportunity for French colonization on such lands, which would not arouse the hostility of the natives. And in fact they have in many cases been favored by the change. A case in point is the huge domain of Ousseltia, northeast of Kairouan, where French colonists as well as landless natives have been granted land, and both have prospered. In the vicinity of Sfax, by regulating the "sia-line" lands (great estates), the French local townspeople and even some former Bedouins have felt secure enough in their titles to the land to warrant their planting millions of olive trees.

In order to forestall the encroachment of the bey or sheik, or to prevent heirs from dissipating an estate, or to do a pious act, Moslem property owners often made an "Habou" of their property. The rules regulating this old Moslem institution could be complied with in two ways: the owner could either place the property in trust for his heirs, using only the income from it till his death, or he could cut off his heirs from all usufruct of the property, sometimes himself as well, in odrer to endow some public charity—usually a mosque, school or hospital. In the first case the Habou is private and the property is administered by the heirs or heir or by an executor. In the second case the Habou is public and is administered by the central office, the Djemaia, of the Habous, founded in 1874. The system of public Habous is quite similar to that of Mortmain in Spain, where gifts in land of wealthy persons, wills of pious members or last-minute death-bed gifts, in the course of centuries, made the Roman Catholic Church fabulously wealthy in real estate. And once this land was in the hands of the church it was not only inalienable but tax free (hence mortmain, "dead hand"). Some private Habous have become public as a result of the death of all the heirs.

Since land in Habous comprised approximately one third of the total area of the Protectorate the question before the French government was to get control of some of this land in order to settle Frenchmen on it. But bad feeling might be aroused if the French arbitrarily took over great areas of land and sold it to non-Moslems. So the first step was to give the natives living on either public or private Habous actual possession of their land. In many cases, although the natives had no title at all to their plot, their title was cleared by virtue of their having been on the land a long time —"occupants immemoriaux." But the cost of registering property is high: 5½ francs per hectare, 120 francs per plot or parcel, besides 5½ per cent. of the total value of the property. If there are a number of plots to be registered, the second must pay 132 francs, and any others 198 francs. Hence many natives could not afford to register the land on which they lived. Finally, by government decree of 1898, the sale or transfer, even to non-Moslems, of Habous—inalienable according to Moslem law—was legalized, and as a result large tracts of land have come into the hands of the Department of Agriculture of Tunisia and have been purchased by Frenchmen.

In the vast expanses of the steppes of

central and southern Tunisia one may travel for miles without seeing either towns or villages. The Bedouin tribes that live there are wandering nomads. They migrate north toward the mountains as the advancing summer sears their pastures and south in October or November as occasional rains begin to fall. Their property consists of animals, not of land, but each tribe had grazing rights to certain areas which were recognized by neighboring tribes. Thus their concepts of land tenure was collective and extensive rather than private and intensive. The individual and the tribe had no right in the land as such, merely in the use of it. The official French view was that collective lands were in reality "dead lands," and, according to the decree of January 14, 1901, these nomadic tribes were granted certain rights, but it was pointed out that the state owned these collective lands and could dispose of them as it saw fit. Since that time an attempt has been made to delimit them. Legally the natives were not allowed to make use of the land without permission of the government, but this has not prevented them from living much as before.

In the military territory of the south, by decree of November 23, 1918, the right of the age-old collective use of the land was accorded the nomads—probably as a sop in keeping them pacified so they would act as a buffer against possible encroachment by Italy from the south. It was not till January 23, 1935, that a law was passed with regard to the rest of the collective land. This law made the registering of land the business of the local Caidat, not of the central government, and its object was to "guarantee Tunisians in the peaceful possesion of their lands." Although land might be alienated by an outsider, if those already on it did not register it within a certain

SMALL VILLAGE NEAR GAFSA

DESERT LIFE CENTERS AROUND THE SPRING AIN, WHICH ALSO MEANS "EYE." THE SPRING IS INDEED THE EYE OF THE DESERT.

NOMADS IN CENTRAL TUNISIA ON THE ROAD TO GAFSA

OLIVE PLANTATIONS AND WHEAT FIELDS ENCROACH UPON LAND ON WHICH NOMADS FORMERLY HAD COLLECTIVE GRAZING RIGHTS. NOW THEY MUST PAY FOR GRAZING PRIVILEGES ON STUBBLE FIELDS.

time, still most of this land was fit only to be used as extensive grazing land. Hence the nomads were largely left to live as before, except in central Tunisia. Here Europeans began growing barley and wheat on an extensive scale on land which the nomads had formely grazed over on their trek north. Now they had to pay for grazing privileges—on stubble fields at that—where formerly their herds had grazed for nothing, and it was very difficult for them to understand the reason for this change and to adjust to these new conditions. On their part, the landowners complain that these nomads are the greatest thieves in the world, who take with them when they leave anything which is not nailed down.

### Settling the Land

Once the French controlled so much land, actually or potentially, the question was to settle Frenchmen on it. But this was no light task. Algeria was already proving difficult, and the French did not want to arouse another group of natives to hostility. But this lethargy on the part of the government had unfortunate consequences. A few enterprising men or land companies bought up vast domains. Of the 443,000 hectares owned by the French in 1892, 416,000 hectares were owned by 16 individuals[1]—an average of some 60,000 acres apiece. The government made some efforts to remedy this situation. The public Habous and huge Moslem estates were put on the market, and feeble attempts at colonization were made. By 1900 there had been some agricultural progress, but again by a mere handful of Frenchmen. The alarming factor to the government was the influx of Italians, either as laborers or as small farmers. As early as 1881 there were 11,000 Italians in Tunisia as against 708 Frenchmen. In the face of this M. Jules Saurin reiterated that Tunisia could be held only if it were peopled by French peasants. Further attempts at colonization were made from 1900 to 1914. 125,000 hectares of land were sold by the government to new settlers, in lots of 100 hectares or more, and vast blocs of steppe land were distributed. But still there was little immigration of French from the mother country. Most of those who took this land were either already in Tunisia or came from Algeria. And by 1914 even one third of these people had sold their land.

Then came the World War. Many of those who returned were not willing to

[1] Jean Despois, "La Tunisie," p. 140. Paris, 1930.

do all the work necessary to put their properties into shape again; furthermore, in view of the very high prices, the temptation to sell was very great. In this post-war period 80,000 hectares, one seventh of all the land held by the French at that time, changed hands. It was bought by the natives, and, especially in the northeastern part of Tunisia, by the Italians.

This process of "peaceful penetration" by the Italians in Tunisia merits our attention. The Italian peasant arrived from southern Italy or Sicily without a penny, but he soon found work at 2 francs 50 a day on the large estate of some Frenchman. He worked hard, he lived on very little, and he put aside 40 or 50 francs a month. In 4 or 5 years he had saved a thousand francs or so, and with this he bought a few acres near the farm on which he worked. Thus he could still make a living working for some one else while working on his own land in his spare time. This explains why the large French estates are so often surrounded by tiny plots owned and worked by Italians. At the end of five or six years his own land was producing enough for him to live on and he could spend all his time on it; he had become a land owner in his own right. This miracle can be understood only in the light of the economic and social background of the Italian. In most cases he had come from a large estate which was under the absolute control of the feudal landlord, where misery and malaria were rampant and the standard of living was as low as during the Middle Ages. Tunisia, where he could own his own land by dint of 10 or 15 years' hard labor, was indeed the Promised Land. Furthermore, the Italian government granted long-term loans to its nationals at only 2 per cent. interest.

In view of these circumstances, the French government was faced with the necessity of adopting new methods in order to attract substantial citizens. The recipients of land had to have a certain sum of their own with which to start farming, and they were held strictly to their agreements. The government was disposed to grant credits to really needy farmers, and 33½ million francs were voted to that end. And schemes for further colonization were elaborated.

But in spite of all French efforts toward inducing Frenchmen to settle in Tunisia, they have been slow in doing so, and the number of Italians has increased. The latter are in a majority in Tunis (49,878 against 42,678 French) as well as in Grombalia (3,859 against 1,938), in Beja (1,685 against 790) and at Mateur (1,169 against 398). In the region of Cap Bon, the large range which forms the southern shore of the bay of Tunis and from which can be seen the island of Pantellaria (called by Mussolini the new Mediterranean Gibraltar), the Italians own over 60 per cent. of the vineyards—13,197 hectares against 9,196 in 1921, whereas the number of hectares owned by the French has fallen from 23,379 to 21,156 in the same period. The Italians are also in a majority in the region of the Kef. Furthermore, for the Regency as a whole the percentage of the total French population engaged in agriculture is very low—only 7.7 per cent. in 1926 against 13.6 per cent. for the Italians. Thus the French feel that they are dealing with a kind of economic boring from within.

### Wages and Leases

One of the problems that has come up for solution, on land owned by natives, French and Italian, is that of labor supply. Before 1900, and even up to 1914, there was little difficulty in finding enough hands for ordinary unskilled labor on the farms—and wages were very low. The harvest season coincided with the influx of nomads from the south.

THE OASIS OF TOZEUR

*Above:* EDGE OF OASIS. THE PRESENCE OF WATER MEANS A PROFUSION OF VEGETATION—DATE PALM TREES, OLIVE TREES AND VEGETABLES—INSTEAD OF BLISTERING SAND. OFTEN TWO OR THREE CROPS GROW SIMULTANEOUSLY ON THE SAME PIECE OF GROUND. *Below:* SCENE IN THE OASIS, WHERE THE LAND, INTENSIVELY IRRIGATED AND FARMED, IS OWNED ALMOST EXCLUSIVELY BY NATIVES IN VERY SMALL PLOTS. NOTE IRRIGATION DITCHES ON EACH SIDE OF ROAD.

MARKET SCENE IN TOZEUR

They did not come in great numbers if the harvest of the steppe had been good, but if their own pastures had been ruined by the drought they came in droves to work in the Tell and the Sahel. And once their summer grazing lands were used for the extensive cultivation of cereals it became even more urgent for the nomads to find summer employment. But the area in crop increases each year, on lands owned by natives as well as by Europeans, and many former Bedouins have become sedentary agriculturalists. Coincident with this there has been a building boom in many towns where relatively high wages have been paid. As a result rural laborers have become scarce. This scarcity has made itself felt particularly in the vineyards and olive orchards, where a great deal of the work must be done by hand. The cultivators of cereals have met the labor shortage by resorting to power farming.

Many native landlords have their land worked under the contract known as khammessat. The khammes is a share-cropper who contributes nothing but his work and who receives a fifth (sometimes a fourth) of the crop. He is usually very poor, and the landlord often advances him money for consumers' goods. But a fifth, or even a fourth, of the harvest which is often poor, and sometimes nothing at all, does not make it possible for the share-cropper to repay his landlord very soon. Thus often he becomes tied in debt slavery to the farm for as long as he lives. This system is gradually dying out, and its place is being taken by that of hiring day laborers. But the system of wage laborers has its dangers as well. Under the contract of the khammessat the peasant, who is in reality often a serf, at least must be kept alive through the slack season, so he can work during the next harvest. This is not the case with the wage laborer. Once the harvest is over and he is paid in cash the landlord's responsibility toward him is at an end. He

THE SPRING WHICH FEEDS THE OASIS OF EL HAMMA

goes to the towns and does anything there is to do. But the slack season in the country frequently coincides with the slack season in town, and the laborer is only too likely to become a member of the unemployed proletariat with an extremely low standard of living.

In the olive orchards an arrangement which has proved rather satisfactory to both landlord and tenant is the contract known as the mgharsa. According to the terms of this planting lease or contract a certain area is leased to the mgharsi whose task it is to clear and plant it in olives. The mgharsi furnishes the tools and the young olive trees, and is frequently able to eke out an existence by growing grain between the trees. Furthermore, this cultivation is valuable in providing a tilth which aids in conserving the moisture in the soil. The proprietor may also aid the mgharsi with cash, but these advances have not resulted in the abuses of the khammessat. As soon as the trees begin to bear the mgharsi becomes owner of one half of the plantation. The great olive plantations of the SFAX have been developed to a large extent as a result of this union of European capital and native labor. Very frequently after the division of the plantation the native continues to care for the trees of his former landlord, and he receives for this service, according to the terms of the contract called mougakate, two thirds of the harvest. This arrangement makes rather needless the continued presence of the landlord, who often lives in the neighboring town. But this kind of absentee landlordism is not what the French government is trying to foster. The time may come when it will be difficult to hold areas which have been partly owned and entirely managed by natives for several generations.

### French, Italians, Natives

It has been a difficult task indeed to colonize Frenchmen in Tunisia. In the

north the Italians, with their low standard of living and their expert ability at raising grapes and making wine, have been able to become small landowners at the expense of the great estates of the French. In central and southern Tunisia the native, with a standard of living still lower than that of the immigrant from Italy, has succeeded in keeping the growing of cereals and of olives largely in his hands—even if the land is often owned by the French. And in the oases the native not only does the work but he owns the land—with but few exceptions. As a matter of fact division of property has gone so far in certain instances that different branches of an olive tree may belong to different people. But the net result is that the land of Tunisia is being legally divided up by natives and Italians, but not by Frenchmen.

Italians comprise over 60 per cent. of the wine growers in Tunisia, they own more than half the area planted in grapes, and they produce more than half the wine. The 77,000 hectares owned by the Italians are a part of the most intensively cultivated land in the Regency, whereas much of the 650,000 hectares owned by the French are in the areas of more extensive cultivation in central and southern Tunisia. Thus a kind of state within a state has been in process of gradual evolution. But this Italian state within a French Protectorate has as its very secure base the land. It is the very stability of this Italian state which alarms the French, who point out that this peaceful penetration of Tunisia by the Italians has been made possible by French control and the security concomitant with it as well as by the capital investments of the French. But the French are realists. They know that the Protectorate can be held only if sufficient people are loyal to France. If non-Frenchmen own great areas of land in small plots they will tend to form a bloc, the loyalty of which to France can with difficulty be expected. The problem becomes not unlike that which confronted Californians with reference to the Japanese. The French do not relish the prospect of having to administer a colony of natives and Italians, with only a handful of Frenchmen—and having to pay for the administration.

This problem has given the French colonial administrators many headaches and sleepless nights. The increase of Frenchmen living in Tunisia is only about 1,000 per year, and of the total 71,000 French registered in 1926, more than 11,000 were naturalized foreigners. The Maltese, naturalized under the Franco-British agreement of 1923, became citizens automatically unless they individually elected to remain British. They numbered 13,500 in 1921, but only 8,400 in 1925, which indicates a rather rapid "assimilation." An act of December, 1923, imperiled the nationality of the 130,000 Italians living there at the time. Under this act, vigorously protested by Rome, it was necessary for the Italians to renew their nationality or automatically become French citizens. This act was suspended for three months, and the suspension repeatedly renewed till 1935. This insecurity kept the Italians in a state of tension instead of definitely settling their problem. Then came the settlement of 1935. All persons who shall be born in Tunisia of Italian parents until 1965 are to have Italian nationality, except that those who are born between 1945 and 1965 may at their option assume French nationality at the time they attain their majority. As early as 1931 the majority of the Italians was apparently checked, "as they then numbered 91,178, and the French, 91,437, the slight excess indicating some success for French policy, or at least for the census officials."[2]

The French policy of assimilation has

[2] Herbert Ingram Priestly, "France Overseas," p. 192. New York: Appleton & Company, 1938.

THE OASIS OF EL HAMMA

*Above:* DUNE ENTERING THE OASIS. *Below:* EDGE OF OASIS. THE TRENCHES AND WICKER FENCES ARE CONSTRUCTED TO KEEP SAND FROM DRIFTING IN.

been countered by Italian Fascist propaganda which has literally flooded the Regency. But this propaganda may overreach itself, as it did last January, 1939, after the speech by Daladier in which he pointed out that not one foot of territory of the French Empire would be ceded away, "that there is no law against the right of France." (*Il n'y a pas de droit contre le droit de la France.*) Vituperation struck a new low in an article of *Tevere*, under the caption "Spit on France." Even many of the Italians were amazed, and found it hard to believe that their country could sanction such journalism. And the result was a big surprise to both French and Italians. In a short time some 5,000 requests to become naturalized French citizens were received by civil authorities. And February 15 a new paper, *Il Giornale*, friendly to France, began to appear in Tunis.

The exploitation of any "backward" country by a "progressive" one means the juxtaposition of peoples with entirely different backgrounds. Friction is apt to be more severe in town than in the country. The French have interfered as little as possible with the urban natives in their trade, handicrafts and customs generally. There seems to be less conflict—open and latent—between French and natives than between Italians and French. The latter have all the good government jobs, they own the mines, the great estates, the railroads and buses, thriving businesses, the chic restaurants. But the tens of thousands of Italians in Tunisia patronize Italian business men whenever possible. The French and Italians mix little, and because of the tension each group emphasizes its loyalty to its mother country. There is a plane of cleavage between the French who own the large estates and the small Italian landowners, but there is what almost amounts to a No Man's Land between the French and Italians who live in towns. This problem can not be more than mentioned in a short paper. Suffice it to say that the cloe or "cyst" of Italians, quite large and firmly knit, could very well act as a Trojan horse in case of open conflict between France and Italy.

Then there is the question of the native. Without a doubt, the productive capacity of Tunisia has increased greatly since it has been in the hands of the French. They have built railroads, hundreds of miles of magnificent highways, many schools and hospitals, bridges, public buildings and, not to be overlooked, huge barracks. The Regency exports great quantities of agricultural produce—olive oil, wheat, barley and wine, as well as minerals such as iron ore and phosphate. Certainly such a development would not have been possible, or at least not for a long time, under the old capricious arbitrary native régime, the taxes of which were burdensome in the extreme. Of these there were very many: the mejba—a poll tax, first established in 1856 which, when augmented in 1863, was the cause of bloody uprisings. There was a tithe on cereal crops which was based on Koranci law and was payable in kind or in money. There was also a tithe on oils, imposed since 1730, and in the daidats of Cap Bon and SFAX, the mradjas—a tax on fruit and vegetables. The native government could never establish its budget in advance because it was impossible to "foretell the amount of resistance which the taxpayers might offer." Indeed, the government was described as "an arbitrary government tempered by insurrection."

The French have changed all this. But has the standard of living of the native been materially raised? Certainly not at all in the same proportion as the productive capacity of the country has been increased. Many great estates export hundreds of tons of grain, which

is produced by the most up-to-date equipment. Yet hordes of natives on the verge of starvation add a few more pounds of cereals to their larders by gleaning in the fields owned by foreigners. It would seem that too little attention has been paid to the living conditions of the natives—they were not even numbered; in the census of 1931 they numbered 2,215,000. But they object that although they help pay for and build railroads, for instance, they have no money with which to buy tickets on the trains. Nor can they get too loud in demanding liberty, equality and fraternity. The French should never forget that Mussolini is the self-styled Defender of the Moslems.

In spite of all the attempts at colonization in Tunisia, French colonists lag. France sends in more money than men, with the result that large estates are still operated by capitalists. The Franco-Tunisian Company, which operates the Enfida, employs 100,000 natives, few Europeans. One third of the foreign-used land is controlled by companies. But the small owners who work their own farms are not French, and, as has been shown, their number is increasing. There is much truth, especially in a dry area like Tunisia, in the statement to the effect that "le meilleur Resident General c'est la pluie," but in the long run the race which sticks close to the soil will probably be in possession of the country. As long as the principle of nationality is invoked, as long as the rulers of nations, like simple peasants, believe in "rounding out their domaines," just so long will the Italians clamor for administration from Italy; and as long as the natives realize that the export of great quantities of foodstuffs and minerals does not coincide with any appreciable increase in their standard of living, just so long will they clamor for self-determination. It is to be hoped that the traditional liberalism of the French will emerge triumphant in their dealings with both Italians and natives. If not—if the natives are not allowed to voice their natural and national aspirations they will be somewhat justified in saying of the French what Calcagus, the leader of the Britons, is reported to have said of the Romans: *Auferre trucidare rapere falsis nominibus imperium, atque ubi solitudinem faciunt, pacem apellant.* (To plunder, to slaughter, to steal, these things they misname empire; and where they make a desert, they call it peace.)—Tacitus, "Agricola," Sec. 30.

A program of concessions to the natives and "appeasement" for the Italians should be motivated by a sense of justice and good-will on the part of the French. If such a program be inaugurated after France has been weakened by the war it will have no moral value. It would only succeed in convincing both natives and Italians that they could and should make greater demands. These the French would, to save face, refuse to grant. All parties might consider the others to be in an untenable position and war or revolution might be the result. The strength of continental France is in a peasantry firmly rooted to the soil, but as has been seen the French in Tunisia have grown only adventitious roots. Only careful diplomacy can prevent the Italians in Tunisia from playing a rôle similar to that played by the Germans in Sudetenland.

# VITAMINS AND SENESCENCE

By Dr. AGNES FAY MORGAN

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VITAMINS have lost their mystery so for as their chemical composition is concerned but still retain some cloak of anonymity so far as their *modus operandi* goes. Instead of A, B, C and D we now have carotene, thiamin, ascorbic acid, calciferol and in addition a large and growing flock of B vitamins besides the original or $B_1$ (now called thiamin). Likewise at least two other fat-soluble factors are known, E or alpha tocopherol and K, a group of naphtha-quinone derivatives. It is no longer *de rigeur* in our best nutrition circles to fall back on the alphabet in designating the vitamins but instead the proper chemical names of these substances are used. This is quite in line with the polite usage of proper names of individuals when the identities are known instead of numbers and letters which might be used when they were still unknown.

## THE B VITAMINS

The B vitamins are grouped together because at one time, until 1919 at least, they were thought to be one substance only, antineuritic or antiberiberi in character. Of course this substance, thiamin ($B_1$), is only one, although perhaps the most overwhelming in the effects exerted by its deficiency, of a group of at least six and possibly eight or ten equally indispensable vitamins. The first of this family of B's to be detached after thiamin (synthesized 1932)[1] was designated G by Goldberger and by Sherman, $B_2$ by the British workers. This turned out to be riboflavin, identified by Kuhn in 1934. It is the chief B vitamin contained in milk and probably in green leaves.

The next separation was that of vitamin $B_6$, named by P. György in 1935, now called pyridoxin or adermin, synthesized in 1938. All three of these factors, thiamin, riboflavin and pyridoxin, can be rather readily removed from water solutions of vitamin rich foods such as yeast, liver and rice bran by shaking such solutions with fuller's earth. In 1936 it was pointed out by Koehn and Elvehjem of Wisconsin, and Lepkovsky and Jukes of California, that after such removal there remained in the filtrate something which was necessary for both chicks and rats, in addition to the three absorbed B vitamins. This became known as the "filtrate factor or fraction." But by 1938 the identity of still another B vitamin was discovered, nicotinic acid, thought to be the chief substance lacking in the diets which produce pellagra.

## THE "FILTRATE FACTOR" DEFICIENCY SYMPTOMS

Now crystalline chemically pure thiamin, riboflavin, pyridoxin and nicotinic acid were available and in this laboratory and elsewhere these with necessary fat-soluble vitamins and a purified basal diet were fed to young rats. After six to eight weeks most of these rats which happened to be black coated began to show silvery gray patterns in the fur. Their growth was impeded and after a few weeks skin eruptions occurred and in most cases their lives came to an end within six to eight months. They took on all the appearance of extremely aged

[1] For an interesting description of this subject see R. R. Williams and T. D. Spies, "Vitamin $B_1$." Macmillan Company, 1938.

*By courtesy of Journal of Nutrition.*

FIG. 1. THE EFFECT OF VITAMIN B ON A RAT FAMILY

NUMBER 2 WAS GIVEN ALL THE B VITAMINS THROUGHOUT THE EXPERIMENT. NUMBERS 1, 3 AND 4 WERE FED THE ANTI-GRAY VITAMIN DEFICIENT DIETS.

animals with loose wrinkled skin, sparse silvery hair, emaciation and sometimes severe and persistent skin ulcers at the base of the tail and on the hind legs and feet. If concentrated extracts of the "filtrate factor" were given them at any stage of the deficiency their condition improved at once with full return to health and color of fur. A photograph of gray and cured rats is shown in Fig. 1 and of a senile-appearing deficient rat in Fig. 2.

### The Glands Involved

Microscopic study of the organs of these rats has shown that the deficiency caused consistent damage to the adrenal glands, thyroids and sex glands and that on recovery the damage was repaired, although evidences of it were left.

It is not clear whether the primary damage occurred in the adrenal cortex or somewhere else, perhaps in the anterior pituitary gland. The latter gland is thought to be the "motor" or master control of several other endocrine organs, notably the gonads, the thyroid and the adrenals. If any of the functions of the anterior hypophysis therefore are destroyed or altered by the vitamin deficiency subsequent changes in the thyroid, adrenal cortex and sex glands may be expected. Thus the depigmentation of the hair may occur through the intermediation of either or both thyroids and adrenals. Administration of thyroid and adrenal cortical extracts has produced slow darkening of the grayed fur of vitamin-deficient rats but has not benefited the animals otherwise. This leads to the suspicion that the deficiency produced poor functioning of these

glands as only one of its far-reaching effects.

The young silver foxes later mentioned as filtrate factor deficient were found on autopsy to have enlarged red-pigmented thymuses as well as evidence of previous but largely repaired damage to the adrenals. It has been reported frequently that victims of Addison's disease, due to destruction of the adrenal cortex, have enlarged and sometimes regenerated thymuses.

When normal stock female rats were given the deficient diet on the day their young were born nearly complete failure of lactation resulted. Deficiency in one or more of the other B vitamins had no such devastating effect. If the endocrine system is affected by the deficiency it is not surprising that lactation should fail since anterior pituitary hormone control of this function is known to exist. Mediation or direct action in initiation of lactation by the adrenal cortical secretion is also generally recognized.

Experiments were made with cocker spaniels placed at six weeks of age on the purified and filtrate factor deficient diet and with results similar to those seen in the rats. The coal-black long curly hair of these pups after two or three months turned gray at the roots and gradually grew out gray in color. One was cured by administering a "filtrate" made from yeast with almost immediate new growth of black fur and increase in weight. A similar diet fed to six young silver foxes, three with and three without "filtrate factor," resulted in the sudden death of one of the deficient animals within seven weeks. The other two were given the missing factor at once to save their lives, but they lost their fur almost completely. Soon a new coat of fur grew in but with white instead of black under fur. They all grew well. One of the controls and one of the gray pelts was made up into a neck piece as a reminder of this experiment.

### Is Pantothenic Acid Involved?

Meanwhile the "filtrate factor" origi-

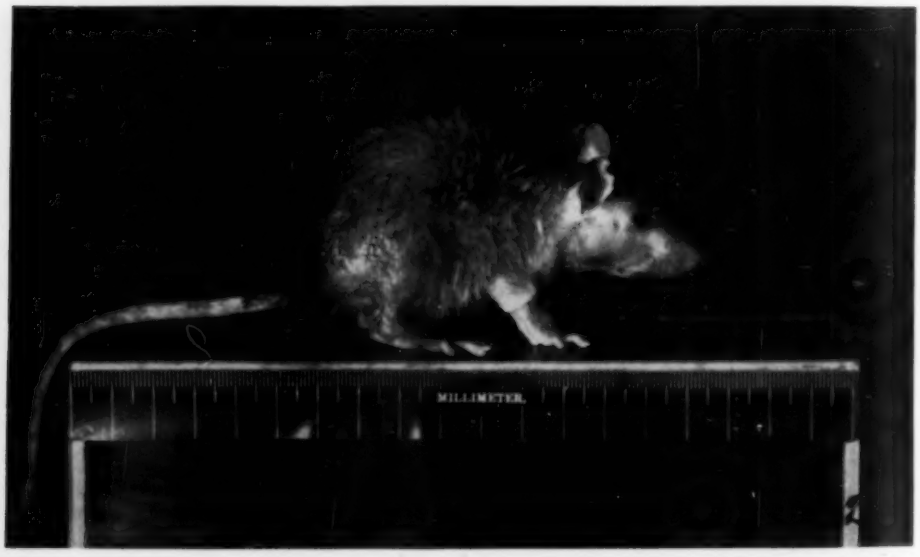


FIG. 2. A VITAMIN DEFICIENT SENESCENT RAT
FIVE MONTHS OLD. NOTE THE GRAYING OF HAIR, LOSS OF HAIR AND WRINKLING OF SKIN.

nally postulated by Lepkovsky and Jukes and Elvehjem and Koehn as necessary for chicks has been identified with the pantothenic acid so long studied by R. J. Williams. This acid has now been synthesized and is becoming available in crystalline form for feeding experiments. Is it or is it not the same thing as the anti-gray hair factor in the filtrate? No complete answer is yet available, but it can be stated confidently that pantothenic acid is concerned in the graying phenomenon, although it is probably not the only factor involved. It is now being fed to rats and dogs both with and without the crude "filtrate factor." Darkening of the gray fur has occurred at least temporarily after some delay when sufficient amounts of pantothenic acid were given.

A rather surprising interrelation between the anti-gray hair vitamin deficiency (which in our early experiments involved pantothenic acid deficiency as well) and nicotinic acid intake has been seen in the dogs. It was assumed that nicotinic acid is essential for the prevention of "black tongue," the canine analogue of pellagra, and that dogs deprived of this substance would exhibit early failure of nutrition. But the animals reared on purified basal diet plus the crystalline vitamin supplements, thiamin, riboflavin and pyridoxin, grew normally and except for gradual and complete depigmentation of the fur and occasional diarrhea appeared to be in good health. One male cocker spaniel remained well except for a dust-mop gray coat instead of his natural glossy black hair after sixteen months on this régime. There were no signs of black tongue at any time. His photograph with a normal control is shown in Fig. 3. But his sister which had received the same diet plus nicotinic acid, lost hair color, appetite and weight after only four months and when apparently about to die was given the "filtrate factor" preparation. She rapidly recovered normal health with normal coat color. The same rapid failure was seen in several other young dogs and also in rats when nicotinic acid was added to the "filtrate factor" deficient diet. Perhaps the anti-gray hair vitamin, nicotinic acid and pantothenic acid participate in the same cycle of tissue reactions, balanced nicely so that omission of one topples the structure but omission of all is less harmful.

A curious phenomenon is seen in the continued growth and youthful appearance of rats fed the usual diet plus yeast and fat-soluble vitamins and an additional daily supplement of yeast filtrate. At two years of age, when stock rats begin to fall off in weight and show signs of failure, these animals are sexually active and of near-giant size, the males being 500 to 700 grams in weight as compared with the normal 350 grams. Some scattered graying occurs in their fur but no general depigmentation. The appetite and efficiency of intestinal absorption are maintained at the level of young adults. One of these super-developed rats along with a normal brother of the same age, twenty months, is shown in Fig. 4. These large animals are sexually mature and physically active, in contrast with the young giant rats produced by anterior pituitary gland transplants by P. E. Smith a few years ago.

### Where Do We Find These "Filtrate Factors"?

So far little progress has been made in the assay of natural foods for the "filtrate factors." Certainly the anti-gray hair fraction is distributed somewhat sparsely in such foods as have been tried thus far. One may be led to speculate as to whether it was originally provided for man as for other animals in the bran, twigs, viscera, insects and other foods now considered inedible. Plantation cane molasses, for instance, has been

FIG. 3. TWO COCKER SPANIELS

FED EXACTLY ALIKE FROM WEANING, EXCEPT THAT THE GRAY DOG (ORIGINALLY BLACK) IN THE FOREGROUND LACKED THE FILTRATE FRACTION OF THE B VITAMINS.

found well endowed with this fraction, but refinery molasses and the crystalline sugars are free from it. Whole wheat and wheat bran (but not to the same degree, wheat germ) contain it but refined flour lacks it. Canning has an adverse effect on the filtrate fraction of the B vitamins and leaching during cooking in water or steam removes it from the cooked food.

A cheap and effective source of all the B vitamins now known might be made up of black strap cane molasses and wheat germ or even wheat bran. Such a mixture is actually in use as a tonic and medicament in at least one student hospital and apparently with satisfactory results. This is a commentary on the remarkable cycle accomplished by industry and science in our food supply, in which we carefully remove the vitamin-rich part of the natural foods, then prescribe the removed offal as medicine! When the removed vitamins are prescribed in the form of pure extracts or synthetic products the whole process becomes ludicrously expensive.

Thus apparently all the processes which civilization has imposed upon our foods tend to remove or destroy whatever part of this fraction is present in the materials which we now regard as fit for human use. The remedy should probably be sought not in the return to primitive feeding habits but in the isolation, identification and thorough study of these as of the other vitamins and the inclusion of suitable sources in the diet.

Of course many prematurely gray people have written to inquire whether there is any reason to suppose that the vitamin will affect their hair color. Some who have tried taking rice bran and yeast concentrates faithfully have reported that the new hair is growing in dark instead of gray. The process is necessarily slow, since hair once gray can not be expected to change color and no one wishes to remove all gray hair and wait for the slow appearance of the new hair of another color! However, if an arrest of the graying process can be obtained this will satisfy many people.

But the more important phase of the application of these findings to humans lies in the possible bearing they may

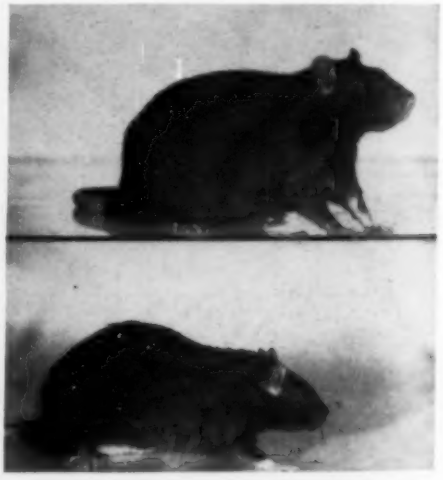

FIG. 4. LITTERMATE BROTHERS

TWENTY MONTHS OLD, FED ALIKE EXCEPT THAT THE LARGER RAT RECEIVED AN EXTRA SUPPLEMENT OF "FILTRATE FACTOR" CONCENTRATE.

have on the prevention of premature aging. Are the adrenals, thyroids and other glands made relatively inactive by diet deficiency and are some of the phenomena of old age the result of such inactivity?[2] Are there long-continued slight vitamin deficiencies which bring about the premature graying and the metabolic and other disorders of senescence? Old age phenomena can doubtless not be deferred indefinitely, but modern living seems to bring them on earlier than need be. Perhaps primitive man obtained more of all the necessary food factors from the unrefined whole plants and animals on which he subsisted than we can get from our refined, milled and cooked dainty fare.

[2] See A. J. Carlson's delightful chapter on the endocrines in "Problems of Aging, Biological and Medical Aspects," edited by E. V. Cowdry, Williams and Wilkins Company, 1939.

In any case if a true interrelation of a vitamin and the endocrine system has been uncovered new means of both experimentation and clinical use of vitamins will result. Some of the treasured mystery of the functioning of both these groups of potent substances may be eliminated.


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## WHEELS

I HAVE always been interested in the relationship of the wheel to the advance of civilization and the rise of man from the state of savagery. There has been a good deal of exploration as to where the wheel was discovered and how it first was used. It is suggested that it came from putting logs under heavy objects to roll them about, and then gradually went on to more refined uses, from transporting of objects and men to more creative or manufacturing uses, such as in the potter's wheel, the spinning wheel and the mill wheel. Our own early American life and our spread across this continent owed much to the wheel, and it now plays a predominant role in our economic structure.

We know that the Eskimos have been able to build up a fairly satisfactory culture without the use of the wheel; what they do, though, is of a very simple character, and their snowy environment has not been conducive to the use of wheels. But upon nearly every civilization of the world wheels have had a profound influence. Few of us pause to realize the power of wheels in our daily life, whirling about us everywhere in the civilization which they have played such a large part in creating. Literally, "Wheels That Make the World Go Round," and "Wheels within Wheels." Not just the obvious wheels we all see rolling under us on trains, automobiles or bicycles. There are the tiny wheels tucked away in watches to tyrannize over us in the matter of time. There are the wheels in typewriters and presses, in engines and machines and other devices about us everywhere. Steamships, airplanes, the tractor and the armored tank alike are impotent without them. Wheels have done much in building up and bringing together man's world; misused, they can the more rapidly destroy it.

Perhaps the most significant effect of the development of the wheel was that it gave mobility to man and increased his range of activities. This mobility has been vastly increased by the steam and now the gas engine in conjunction with wheels, tracks, roads or water. Wheels mean movement. Movement means danger, unless that movement is controlled. Wheels have made possible a military attack which is unprecedented and which, as we have recently watched it develop on this earth, may bring revolutionary changes in all human affairs.—*Ray Lyman Wilbur in School and Society.*

# SOIL DYNAMICS

By Dr. C. C. NIKIFOROFF

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THE surface of the earth is a field in which mineralogy, biology, physics and chemistry cross and recross their paths, collectively working for the creation of the peculiar epidermis of the land which is known to us as soil.

The soil is not merely a heterogeneous mass of different products of disintegration and decomposition of rocks and not just dirt from which plants can grow. It is a harmoniously organized dynamic system minutely coordinated with its environment including geological history, climate, relief and biological pressure. It is said that any normal soil is in equilibrium with its environment. Such an equilibrium or "steady state," however, is not a state of static rest as might appear to a casual observer: it is a state of continuous readjustment to the ever-changing environmental factors such as climatic conditions, biological activity and erosion. The equilibrium between the soil and its environment does not spring into being spontaneously but evolves gradually through an intricate pedogenic (soil-forming) process which consists of various physical and chemical changes of the original material.

Reaching an equilibrium does not indicate the end of the soil-forming process. This process never ends as long as the soil exists; when it ends the soil dies, becoming a relic or fossil, and ceases to be a dynamic body.

The continuity of the pedogenic process does not contradict the equilibrium between the soil and its environment. The fundamental characteristic of the pedogenic processes is their cyclicity. In this respect they differ from the concurrent geological processes which can be regarded as straight-line processes. The latter begin, develop and end at some static stage at which their products may rest unchanged for a full duration of geological ages. The best illustration of such a difference is the formation of soil humus and of various organogenic geological deposits such as coal, mineral oil, peat and petrified wood.

Every soil contains certain amounts of humus ranging from a fraction of one per cent. to as much as about 20 per cent. according to the type of soil and degree of its biological pressure. The content of humus is relatively constant in every soil adjusted to its environment. The amount of humus is constant but humus itself is not everlasting; it renovates itself continuously. Continuously certain parts of it decomposes into the simple end products such as water, carbon dioxide and mineral salts and simultaneously an equal amount of it is formed anew from the organic residues. The radiant energy captured in organic compounds is turned over to humus and released during its decomposition. Every molecule of soil humus is in a permanent state of transformation. Every quantum of its energy is in a slow but ceaseless motion. The matter and energy which yesterday were a part of living organisms are in soil humus to-day and will be released to-morrow in the form of elemental constituents ready to be resynthesized and utilized by the next generation of organisms. These migrations of matter and energy develop in cycles.

The same organic residues give rise to the organic geological deposits, peats, oils, coals, but the process of their transformation is fundamentally different. The residues do not decompose into the simple end products and do not liberate

their energy. They undergo sterilization, carbonation or petrification and pass into a static stage of conservation. Their potential energy becomes dormant and may rest as such for the duration of the geological eras. Unlike the carbon of humus the carbon of coal does not disseminate as carbon dioxide ready for the photosynthesis of the carbohydrates of plants. The migration of matter and energy from living bodies to the geological formations proceeds along a straight line. When it reaches the static state, it ends in rest.

Cyclicity of the soil-forming processes in so far as matter is concerned can be demonstrated in many ways. The cycles of carbon, water, nitrogen, sulfur, phosphorus and so forth are well known. The cycles of energy, however, are not as yet sufficiently clear.

The immediate sources of energy involved in the pedogenic cycles are cosmic, especially the radiant energy of the sun and a potential energy of crystallization concealed in atoms, molecules and crystals of minerals. Applying the terms of geochemistry to geophysics, these forms of energy may be distinguished as the vadose (of superficial origin) and juvenile (deep seated, issued from deep within the earth) energy of the pedogenesis.

The vadose energy is introduced into cycles through a photosynthesis of plants, the equation of which is:

$$6CO_2 + 6H_2O + 677.2\ \text{Cal} = C_6H_{12}O_6 + 6O_2$$

and by numerous endothermic reactions which take place in the soil itself.

Juvenile energy is liberated by the weathering of rocks through a decomposition of minerals. The bulk of rocks is composed of alumosilicates. Alumosilicates are endothermic compounds which were formed by crystallization of magmas under conditions of high temperature and high pressure. The decomposition of these minerals on the surface of the earth is accompanied by an emanation of heat. Clayization of one gram of granitic rock liberates about 120 calories.

The soil is a medium in which vadose energy and juvenile energy merge and pass through intricate channels of the soil-forming reactions.

Obviously the pedogenic cycles do not develop entirely within the physical media of the soil. Certain segments of them pass through the biosphere. Matter and energy leave the soil for living bodies and return to it in the substance of humus. Naturally only the segments of cycles which pass through the soil are of primary interest to soil science. The others belong to the closely related disciplines of biophysics and biochemistry.

As the epidermis of the earth, the soils are naturally subject to a general geological weathering. Consequently, in the soil the strictly pedogenic cyclic processes are intimately combined with the straight-line geological processes. In fact the latter constitute an essential part of soil dynamics. Cyclicity of migration of matter and energy through the soil and life does not indicate that the same atoms of matter and the same quanta of energy continuously travel from the soil into the biosphere and back into the soil. Certain and probably large quantities of both matter and energy continuously leave the cycles, being disseminated in the atmosphere, removed from the soil by leaching for ultimate concentration in the universal ocean, or statically fixed in compounds stable in a thermodynamic environment of pedogenesis. An equilibrium, however, can not suffer any losses, because any loss would immediately disturb the balance. The losses are covered by equivalent amounts of new materials and by new energy which become involved in the rotation partly by living organisms from the cosmos and partly by decomposition of the rocks which release elements and potential energy from the clasps of petrification.

In the soil which is in dynamic equilibrium with its environment the pedogenic cycles are precisely adjusted to the concurrent geological processes so that losses and gains of both matter and energy are continuously and remarkably balanced.

The pedogenic process takes place in the medium designated as the soil body which is a layer on the surface of the earth affected and reorganized by this process. The thickness of such a layer ranges from just a few inches to several feet; in a relatively few instances it exceeds ten feet. The average thickness of various soils depends upon the type of climate and vegetation which are instrumental in development of these soils, upon the nature of rocks, upon the relief of the land surface and upon the soil's own age.

Every soil body consists of several soil horizons. A soil horizon is a part of the soil which develops its individual physical and chemical characteristics, due to a concentration in this part of body of some particular reactions of the pedogenic process. It can be a local intensification of hydrolysis; of oxidation of certain compounds; of solution or coagulation and precipitation leading to an accumulation of various salts, colloidal materials or humus. The reactions which take place in different horizons may be predominantly exothermic or endothermic. In the development of some horizons the release of vadose energy may be the main factor whereas the development of the others may depend chiefly upon liberation of juvenile energy. In some horizons kinetic energy undergoes fixation whereas in the others potential energy is put to work. Due to these differences each genetic horizon of the soil acquires an individual chemical character as well as an individual thermodynamic coefficient. All horizons of the soil body considered in their natural sequence from the surface downward constitute collectively a soil profile.

A fundamental feature of the true soil horizons is a genetic relationship between all horizons of any given profile. All horizons of the profile develop in unison, simultaneously and usually from essentially the same original material. Their dissimilarities, physical or chemical, no matter how great they may be, are due entirely to the harmonious changes of the original parent material. A development of any one horizon is a necessary accompaniment for the development of the other horizons in the profile.

An equilibrium of the entire system presupposes the equilibria of all its integral parts. Consequently the normal horizons do not grow indefinitely after they reach the stage of equilibrium with the environment. The old rather philosophical concept that the soil evolves, develops, grows old and finally deteriorates has not been based on facts. Soil indeed may change its character, but it changes according to the modifications of the environment. Otherwise it remains constant.

It is true, however, that in some particular instances the straight-line geological processes which may take place in the media of the soil profile are strong enough to dominate the strictly pedogenic activity in the soil. They may lead to the actual growth of certain characteristics. An illustration of this is the formation of certain static products which are stable in the existing thermodynamic environment of the soil; for example, the petrified hardpans. The petrification of the hardpans might develop as a by-product of pedogenesis. Because of the stability of the hardpan in its thermodynamic environment its formation terminates the migration of matter and energy in the zone paralyzed by petrification. Such a hardpan can be regarded as a soil horizon affected by a sclerosis. It may grow and in some instances may ruin the original soil.

There is a fundamental difference between the soil horizons and mechanical layers of stratified parent materials. In many instances a soil develops from parent material composed of several strata differing from each other. Each of these strata might have been formed at different times, by different agencies and from different materials. A thin veneer of loess or wind-blown sand may be deposited upon glacial till; a mantle of deluvial assorted drift may be deposited upon the residual detritus or upon the same loess; strata of coarse gravelly alluvium deposited by the swift current may be interbedded with the silty or clayey alluvium settled from the slowly moving water. Each of such layers accumulates above the other at different times; one might be formed by ice, another by water and the third by wind. One might be formed from a nearby source of material and another transported from a great distance. Each layer can differ from the other, physically and chemically, but individual properties of any one of them have no relationship to those of the other layers.

In many instances such layers are so thin that an evolution of the soil profile embraces several layers. In such instances different genetic soil horizons or certain parts of them might develop from the originally dissimilar parent materials so that differences between horizons which develop due to the evolution of soil profile might be superposed upon the differences of the original materials. The individual features of the soil horizons which develop due to a pedogenic process are distinguished as the *acquired* characteristics and are contrasted to the *inherited* ones which are due to the nature of the original material.

The soil as a whole is an unconsolidated porous body. It consists of the three phases: solid, liquid and gaseous. The solid phase forms a mechanical framework or a skeleton of the soil body. It consists of the more or less loosely connected fragments of rocks and minerals and various products of their decomposition. These primary units range in size from the ultramicroscopical colloidal particles to grains of considerable size.

The fundamental physical property of the soil is its texture. The term *soil texture* connotes the effect of its mechanical composition, that is its arrangement from particles of various sizes taken in certain proportion to each other and mixed indiscriminately into a more or less uniform mass. The primary particles, or mechanical units of the soil material, are produced by a physical disintegration of rocks and their chemical decomposition, the mechanical composition of this material, however, in many instances is the product of an assortment and redeposition of the primary units by water, ice or wind.

Closely related to the texture is *a soil porosity* which represents a ratio between the solid and other phases of the soil body. The pore space forms a system of interconnected voids and vessels through which pass the flow of soil solutions and gases, therefore, a qualitative aspect of soil porosity, that is a pattern of distribution of the pore space throughout the soil body has a particular significance for soil dynamics. The same or very similar porosity of the soils of different textures might have a fundamentally different pattern. The ratio of capillary to noncapillary porosity is especially important because of its bearing on velocity of circulation through the soil of its mobile components.

To a considerable extent the texture and porosity determine a *soil consistence.* The soil consistence depends upon the mechanical composition of the material as well as upon an arrangement of the mechanical units in regard to each other which relates directly to the pattern of the pore space in the soil. Unlike soil texture, soil consistence represents a con-

dition of the soil material rather than its constant characteristic. It is subject to changes according to the moisture conditions. Certain amounts of water absorbed by the soil give to it a degree of plasticity and viscosity. The grades of plasticity range from a maximum in the soil of the finest texture to a vanishing point in the soils of the coarsest texture. The grade of friability, or of a lack of an adhesion among the primary particles, ranges in an opposite direction. Plasticity, viscosity, friability are the examples of various forms of the soil consistence.

Finally, soil science attaches much significance to the *soil structure* which represents an arrangement of the primary particles of soil material into various aggregates. A development of structure fundamentally changes the qualitative aspects of soil porosity because of the formation of comparatively large voids between the aggregates. Like a consistence, soil structure refers to a condition of soil material rather than to its permanent property. It also is subject to changes according to the moisture condition. Usually soil structure is expressed best in the air dry soil. An increase of moisture tends to decrease stability of the aggregates and to reduce the structure of soil material to a vanishing point.

Texture, porosity, consistence and structure together with color are the most striking physical characteristics in which the genetic soil horizons differ from each other. The normal soil develops from parent material which in a broad sense is more or less uniform as regards its color, texture, porosity and consistence. Various modifications of these properties in different parts of the soil body reveal the story of soil genesis without an understanding of which soil dynamics can not be fully understood. Such changes are neither exclusively physical nor exclusively chemical. Soil physics and soil chemistry work hand-in-hand in carving a soil profile from its parent material. In some instances chemical reactions cause a change in physical properties, whereas in others, physical changes of the medium either stimulate or retard the chemical processes. This is particularly significant for a distribution of the pedogenic activity throughout the soil body and conspicuous local intensification of certain reactions in particular horizons of the soil profile. For example, an intensification of hydrolysis in some part of the soil body may lead to the formation of more clay in this part than in the others. This addition of clay fundamentally changes the texture, consistence and porosity of the original material. It changes the extent of surface area of the solids, the pattern of the pore space, velocity of movement of the solutions through this part of the soil, and its heat conductivity; it stimulates the development of a new form of structure which is different from that of the original material; it changes its color. Such changes in turn affect the energy and modify the character of the chemical reactions due to which they have been developed.

The pedogenic process operates in a medium characterized by the uneven and continuously changing conditions of temperature and moisture. Diurnal and annual fluctuations of the temperature and humidity of the air do not cease abruptly when the climatic elements emanating from the higher strata of the atmosphere strike the surface of the earth. The climatic waves originated in the atmosphere penetrate the soil for a short distance below its surface. Such a penetration into the soil of the alternating waves of heat and cold as well as of the maximum and minimum moisture is marked by a fast decrease in velocity of transmitting of the heat and moisture from one layer to the other, and by a decrease of the amplitude of waves. This depends upon changes of the medium through which the climatic forces are spreading. From the gaseous medium of the atmosphere

they enter the porous-solid medium of the earth's crust characterized by the different absorbing power and conductivity for both heat and moisture.

The depth of pentration of the climate beyond the surface of the soil is rather small; perhaps, its maximum nowhere exceeds about ten feet. The character of functions of climatic elements beyond the surface of the soil, however, is so different from that above this surface, that the "soil climate" is considered sometimes as something fundamentally different from the "air climate," although such a distinction is, perhaps, not entirely justifiable.

Mechanism of the soil climate can be illustrated by a short discussion of the temperature of the soil body.

Perhaps, the diurnal maximum of temperature on the surface of the soil occurs simultaneously with its maximum in the air above the soil, although in many instances the temperature of the surface soil is considerably higher than that of the air. A few centimeters below the surface the daily maximum will be reached, perhaps an hour later than on the surface. Penetration of the crest of the heat wave (that is, of the daily maximum) for the same distance of a few centimeters below this level will take a much longer time, perhaps three or four hours. At some depths, depending upon the character of the soil and other factors, the daily maximum will be reached when the temperature on the surface will be at the point of diurnal minimum which will send into the soil a wave of relatively low temperature.

Together with a progressively decreasing velocity of penetration of the soil by the alternating relatively warmer and relatively colder waves, the amplitude between the maximum and minimum decreases progressively to a vanishing point also. At some depth from the surface the temperature does not change during the dirunal periods, although it gradually changes from the annual maximum to the annual minimum. The annual waves of heat and chill travel through the soil body slower but penetrate deeper than the diurnal waves. At certain depth the temperature of the soil is not affected by annual changes of the temperature on its surface and remain constant. Perhaps, at this level the climate ceases to affect the earth's crust, and maybe ceases to exist.

The heat is transmitted from a relatively warmer to a relatively colder body. When the surface of the soil is warmer than the interior, the heat wave moves downward. When the surface is colder, it moves upward.

The waves of moisture traverse the soil body in a somewhat similar way although with less regularity. Moreover, the transport of moisture through the soil is affected by the capillary forces, gravity, vaporization, condensation and transpiration by plants.

Consequently the temperature and moisture of the soil, which mutually affect each other, are never uniform throughout the soil's body. These inequalities together with a difference in aeration cause uneven biological and biochemical activity as well as uneven energy of chemical and physical attacks upon the mineral framework of the soil in various sections of the soil, which, in turn, leads to a differentiation of individual genetic soil horizons.

Obviously none of these processes can be fully understood without a knowledge of the thermodynamics and hydrodynamics of the soil, of the chemical and physical composition of the soil body and especially of the behavior of various components in the thermodynamic conditions of the pedogenesis.

Until quite recently the total analyses of the whole soil materials and of some particular mechanical fractions (colloids) separated from such materials formed the backbone of chemical investigations of the soils. These analyses demonstrate a mass effect or a sum total of

chemical changes in different horizons caused by a great many concurrent reactions which take place in the soil, but they fail to demonstrate the individual additives of such a sum total, their nature and their relative value in the summarized effect. The aspect on which these investigations have failed to throw light, however, is of the utmost importance.

The solid phase of the soil is a heterogeneous mixture of many different minerals and every mineral individually is a heterogeneous system of several constituents. A chemical composition of most minerals can not be expressed by stochiometric formulas although each of their constituents is a definite stochiometric compound. Crystallization of minerals from melted magmas or from solutions or meltings, unites these stochiometric compounds into definitely oriented systems (crystals) in certain although not stochiometric proportions. A definite orientation in space of different constituents whether of atoms or of groups of atoms is an essential characteristic of the crystals. The same stochiometric compounds, taken in the same proportions but differently oriented in space in regard to each other, produce the different crystals.

Various minerals behave differently in thermodynamic field of the soil formation in which numerous reactions of decomposition, recrystallization and reorientation of crystals take place. This should demonstrate a complexity of the chemical and physical life of the soil and the inevitability of fatal shortcomings of the summatory analyses to reveal the important details of the mechanics of pedogenesis.

An application of x-ray analyses has opened the door for a new approach to the problem; and in spite of its novelty has already made it clear that soil chemistry will have to lean more and more toward the mineralochemistry in general and the chrystallochemistry in particular. The outstanding problems to be solved by soil chemistry on its new path include not only an investigation of the chemical composition and chemical structure of the minerals which form the solid phase of the soil, but also, and especially, of their behaviors and metamorphism in the thermodynamic environment of the soil formation.

Weathering of the massive rocks and of their fragments, large and microscopically small, is a straight-line geological process. One may trace a gradual transformation of granite into a clay; or of some other rock into a pure quartz sand. The rocks are a source material, the clay and sand, the end product of weathering in the existing conditions. Probably the name, "end product," is not entirely correct. The end product should be a static formation absolutely stable in the given thermodynamic conditions. Such products, even if they actually form, do not accumulate on the surface of the earth; if they would, the earth would be wrapped in an inactive, lifeless mantle. Geological erosion takes care of the removal from the surface of such dying off material as fast as it forms, continuously exposing to weathering fresher material, thus providing a continuous flow of energy and matter into the zone of pedogenesis.

Figuratively speaking, the cyclic pedogenic processes begin where the weathering ends. This does not mean that the beginning of the soil formation ends the weathering. It has already been pointed out that both processes concur in the soil. Weathering continues to attack the mineral framework of a skeleton of the soil within the soil just as actively as outside it, and likely even more actively.

A conspicuous feature of the strictly pedogenic processes is the participating of the living substance in them. In fact the sphere of soil formation can be determined as a part of the crust of weathering invaded by living organisms. The relationship between the soil and living nature is so close that without much ex-

aggeration it can be said that the soil is a storeroom, a nursery, a bridal hall and a cemetery of the entire organic world.

A general trend of the biolgical activity and the biological pressure determine the character of the soil more effectively than any other factor and probably even more than all the other factors together. Organisms involve into the pedogenic cycles tremendous amounts of radiant energy and the new elements such as carbon and nitrogen. Moreover, if the weathering of a mineral framework of the soil does not keep pace with the energy and requirements of the life, living substance itself stimulates the weathering and attacks the minerals with powerful enzymes.

An introduction of life immensely increases the complexity of a pedogenic process. It adds an immense variety of organisms to the multitude of minerals. The living substance, or a sum total of living organisms covers the surface of the earth by an almost continuous film. This substance represents a peculiar geochemical formation. Probably it is a crown of weathering, its final and the most elaborate product. The outstanding features of this formation are its dissemination into innumerable individual organisms each of them enjoying a relative independence from the others; its continuous and rather fast renovation, and an exceedingly high dynamism. The distribution of living substance throughout the land surface, its congestion in some particular region and a relative scantiness in the others, is regulated by the natural environment. The amount of life at any particular place is in equilibrium with its environment which determines certain limits for the expansion of life. Within these limits the life, so to say, saturates the surface of the earth. Such a saturation point is a point of equilibrium. At any particular and stable environment, the amount of life is relatively constant and represents a grade of the biological pressure adjusted to this environment.

Biological pressure, whether expressed in tons of living substance per unit area or in quanta of its energy, is one of the most powerful factors of pedogenesis. The field of pedogenic activity is swarming with micro- and macrobiological population, is thoroughly penetrated by the roots, blanketed with organic residues and enriched by the products of decomposition of these residues. These react with the products of decomposition of minerals. Various exothermic and endothermic reactions are taking place, and it is this ceaseless activity, this continuous flow of energy and matter, which makes the soil a dynamic system.

A laboratory investigation of soil chemistry and physics is made in samples of soil material. The soil material, however, is not a dynamic soil. The samples of soil material do not represent the soil any better than a piece of wood represents a living tree. Therefore soil physicist and soil chemist know that sooner or later they will have to take their precious instruments and reagents to the field and there check their diagnoses on a living body of soil. They know that what they are studying now in laboratories is only a preliminary exploration of the fundamental laws which control the function of soil formation in nature.

Naturally most of the investigations in the field of soil physics and chemistry are concerned with some particular aspects of the problem. Many of them are not as yet properly coordinated with each other due to the vastness and relative novelty of the field. Much work still remains to be done before the fundamental problem of soil dynamics can be attacked. This problem is concerned with the soil-forming cycles of energy accompanying the cycles of matter and with giving to the process an exact mathematical expression.

# THE PHYSICIST AND EVOLVING CIVILIZATION

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NOT so many years ago the run-of-the-mill citizen thought of a chemist as the man in the drug store who made up the doctor's prescription, and he thought of an engineer as one who had charge of the machinery of a steamship or who chauffeured a locomotive. The chemist, because of his well-defined field of operations, and some excellent publicity, has come to be recognized for what he is, a manipulator of atoms and groups of atoms who investigates how and under what circumstances they join with each other or part from each other to form new substances with new properties. The engineer, also, even more than the chemist, is now recognized in his role, for he is the industrial interpreter of scientific progress.

But I am afraid that even to-day the science of physics remains a somewhat nebulous concept to the man in the street. There is a persisting spontaneous association—which is vaguely known to be wrong—of physicists with castor oil. One reason for this is that the purveyors of physics for consumption always appear incognito as doctors, astronomers, marine engineers, aeronautical and communication engineers, and many others. There is no such thing as a physical engineer. The field of physics is broad, and each of its manifold subdivisions has its own name which, with few exceptions, contains no "physics."

Physics is broad because it has to do with the properties of matter in general, in those changes and relations which do not involve chemical change. It is true that the simpler manifestations of physics seem far less mysterious than those of chemistry. The floating of a stick on water does not have the mystifying quality of its consumption by fire. Nevertheless, the nature of atoms, what they are composed of, their relation to electricity, their disruption and reformation, their interaction with light, the nature of collisions between them, are all physical questions. We must add to this list the laws of atomic dynamics which bridge the gap between physical and chemical properties. It thus appears that a synthesis of the physics of the atom must lead to its chemistry so that physics is the fundamental science. Its effect on mathematics will appear shortly. Through chemistry, but also through the tools for which it is responsible, physics also underlies biology, medicine and even psychology.

No one phase of human activity can be separated from the social organization as a whole. This is true of science. Down the course of history the cross-links have been manifold between science and other human activities, the production processes, trade and communication, warfare and the arts. The needs of an era have given direction to the scientific activities and scientific discovery has reacted on society. The slogan of science for science's sake is as false historically as it would be sterile socially.

The Egyptians were faced by the problem of surveying the landholdings which the Nile inundated. The river often changed its bed and it was necessary to re-establish boundaries and areas for taxation purposes. As a result they laid the foundations of geometry. It was healthy because it was empirical. It was amazingly exact. Later the Greeks were to systematize it with good

results, but were also to distill it from its earth-born origin into the realm of pure thought, with unfortunate results.

In the same era there was sufficient optical knowledge for the design of simple optical instruments. The Alexandrians knew the fundamental law of magnification, and Euclid treated the geometrical principles of reflection. Ptolemy had investigated the law of refraction and Archimedes is supposed to have constructed concave mirrors to use as burning glasses. Yet the social needs which were to stimulate the exploitation of this knowledge did not arise until the Dark Ages had passed. Then the advent of printed books created the need for an aid to vision and spectacles were invented. Two spectacle lenses made a telescope, which, turned to the heavens, helped solve the important problem of determining longitude on the long western voyages of that age. Newton's interest in the refraction of light is traceable to the colored fringes which invariably surrounded the images in the early optical instruments.

This gets us somewhat ahead of our story. Archimedes was also interested in levers and was prepared to move the world, if only some one would furnish a fulcrum. Nothing much seems to have come of this, although here was a possible foundation for a development of machines. On the other hand, music, athletics, architecture, sculpture, the drama and philosophy flourished. These fields were the natural outlets for the social energy of citizens whose material needs were taken care of by slaves. A slave economy is not conducive to scientific advance, for those who engage in the productive processes have no incentive, and contact with crude matter is beneath the social status of the citizen.

The sun and the stars in their courses furnished mankind with his only clock and calendar at the earliest stages of civilization. The positions of the stars at sunrise or sunset determined the sowing of crops or the preparation for the rainy season. The study of the heavenly motions naturally followed. The geocentric view could suffice until the determination of longitude at sea made a simpler scheme for predicting the positions of the planets desirable. The Copernican theory met this practical necessity and came into general use in navigation long before there was adequate evidence for its adoption.

Even that pseudo-science, alchemy, was a response to a pressing social need. The ruling classes of the dark ages had need of greater income for their wars and their living than the serfs with their slow rate of wealth production could supply. Gold was the desideratum, and alchemy proposed to supply it. May I point out that to-day we can produce wealth faster than we are prepared, socially, to use it. Power lies in other things than gold. That we go on mining it makes us appear even more foolish than the alchemists.

We know from his writings that Newton was interested in the problems of industry and commerce. Artillery was a new weapon in his time, but the laws of ballistics had not been discovered. Newton laid the foundations of this branch of science when he formulated his three laws of motion.

It is worth noting that the group whose meetings marked the beginning of the Royal Society of England, for years the leading scientific society of the world, drew up an outline of their prospective endeavors. To quote a chronicler who recorded their purposes:

> They design the multiplying and beautifying of the mechanick arts. . . . They intend the perfection of graving, statuary, limning, coining and all the works of smiths in iron or steel or silver. . . . They purpose the trial of all manner of operations by Fire. . . . They resolve to restore, to enlarge, to examine Physick. . . . They have bestowed much consideration on the propagation of Fruits and trees. . . . They have principally consulted the Advancement of Navigation. . . . They have employed much Time in

examining the Fabrick of Ships, the forms of their sails, the shapes of their keels, the sorts of Timber, the planting of Fir, the bettering of pitch and Tar and Tackling.

We have come far since those days. The theory of relativity has stripped the cloak of mysticism from space and time, laying bare their intimate relation to—yes, their interdependence with matter and energy. Quantum theory rubs noses with practicality in the electric eye, x-rays, mercury arc rectifiers, sodium lamps, fluorescent lighting. Wave mechanics links the strength of materials to the conduction of electricity in metals, and to the non-conduction of insulators.

In any discussion of the relation of science to human advancement it is necessary to recognize the difference between the scientific approach, which is rooted in actual facts and relationships, and counterfeit science, which reaches conclusions by arguing from intellectually acceptable premises. What makes it counterfeit is that the premises, while possibly related to facts, exist on a supposedly higher plane of reality which puts them beyond empirical test. Yet the conclusions from these premises are supposed to have validity in the world of reality.

The physical sciences have largely rid themselves of this incubus, but because the social sciences have not it is worth while to look back at a famous example. It is Euclidean geometry.

The supposedly self-evident postulates of that system were no more than a summary of then existing geometrical experience with physical objects. But the philosopher requires something beyond empiricism. Accordingly, this limited realm of human experience must needs be endowed with a super reality so that universally valid conclusions can be reached. The progress of science was, however, to deflate such intellectual arrogance by showing that only within distances ranging between several atomic diameters and several times the earth-moon distance was Euclidean geometry valid, and only as far as we could tell in view of our inaccuracy of measurement. Mathematicians, themselves, were to show that Euclidean plane geometry was only a special case of the two-dimensional geometry of surfaces in general.

This should not be construed as an indictment of pure mathematics. Since the Grecian era the mathematician has become more sophisticated. He knows now that he is interested in exploring as far as he can the relations of a set of concepts which may or may not bear any resemblance to parts of the physical world. Unhampered by questions of physical reality, he has investigated many possible types of relationship and deduced the consequences thereof. The scientific value of these self-consistent flights of pure fancy lies in the circumstance that time and again a certain portion of the physical world has been discovered to be linked together more or less exactly in accordance with one of these sets of mathematical assumptions. And then the theory can be applied as a whole.

Imaginary numbers are a case in point. The square root of minus one, $\sqrt{-1}$, was invented by the mathematician to fill a gap in the real number system, for in that system the square roots of negative numbers do not exist. The mathematician had the satisfaction of finding that the newcomer helped to explain the behavior of real numbers, but otherwise it was purely ornamental.

Meanwhile the electrical art was developing. Certain advantages were appearing in the use of alternating rather than direct current. It became necessary to find a mathematical technique appropriate to the new physical relationships. The mathematician had it ready to hand in his explorations with $\sqrt{-1}$. And so they were married, $\sqrt{-1}$ to 60 cycles, and they have lived together happily and usefully ever since.

It would be wrong if I left you with

the impression that scientists have not been guilty of the sins of pure reason in their own field. Time and again scientists have been baffled by seeming contradictions, which were only contradictions in terms of a description carried over into a newer region of nature from a well-explored region. We have had to learn, for instance, that the laws of the world of baseballs and balloons are the syntheses of those that describe the world of nuclei, atoms and light quanta, and that for astronomical distances, times, temperatures and pressures still another description is required.

Having already discussed the general historical relation of science to society, I want now to examine a few of its more fundamental contemporary social consequences. What the more recent specific contributions of physics to our mode of life have been can well be left to such an excellent book as Professor Harrison's "Atoms in Action."

It is instructive to spend a few minutes in examining a single scientific development. It would be hopeless to try to reproduce all the groping, searching, thinking, guessing, trying, testing and repeating of tests that are an essential part of the scientific method in action. What I hope you will grasp is some of this, and also some idea of the diversity of specialized knowledge and skills which must be tapped and the material resources which have to be available. What is chosen for examination is of little moment. A brief chapter from the history of the incandescent electric light will do as well as anything.

The new incandescent lamp of 1911 had a filament of drawn tungsten wire in an evacuated glass envelope. The isolation of tungsten had been a chemical contribution, its drawing into fine wire a triumph of metallurgy. The outstanding suitability of tungsten as the filamentary material was recognized as a consequence of its high melting point, for the study of heat had revealed that the higher the temperature of a body, the greater the fraction of the energy from it which appears as visible light.

The creation of a sufficiently good vacuum was the culmination of a development which von Guericke had started with the invention of the first air pump and which was to reach its final stage, as of to-day, in the non-mechanical condensation pump in which a condensible gas of heavy molecules like mercury vapor is used to blow the lighter molecules of air and water vapor out of the vessel to be exhausted. The mercury vapor is not actually blown through the lamp, but the same effect is obtained by connecting the lamp to the pump in which a blast of the vapor entrains the air molecules. A cold zone in the connection to the pump, kept cold with liquid air, prevents mercury from getting into the lamp, and the mercury in the exhausted gas is condensed out by cooling with water.

The art of glass making and blowing was necessary to the bulb. To carry the current from outside to inside a metal whose expansion with temperature matched that of the glass had to be used. If this metal shrank too rapidly on cooling it would pull away from the glass as the seal cooled, and if it shrank too slowly the stress created on cooling would crack the glass.

One undesirable feature of the lamp was its blackening with use. This was thought to be due to chemical attack on the filament by gases which developed inside the bulb. But practically nothing was known about chemical reactions in the range between 2,000 and 3,000° C.

Research was undertaken primarily to gain an understanding of phenomena which occur at low gas pressures and high temperatures. It developed the following facts which are a few among many others of great importance. Glass contains large quantities of water which is given up to a vacuum when the glass is heated. This evolution of water vapor

continues for many hours at any temperature, but by heating the glass above the temperature at which it will be finally used, it can be reduced to a negligible amount. A minute quantity of water vapor induces a progressive blackening of the glass, as does hydrogen, which strangely enough does not react with tungsten. On the other hand, oxygen, which does react with tungsten, has no such effect.

These were valuable facts, but of equal significance was the discovery that even when all trace of deleterious gas was permanently absent, blackening still occurred. This was discovered to be the result of the natural thermal evaporation of the tungsten. At the time it appeared to offer an insuperable barrier to a further increase in lamp efficiency.

The all-important reason for using vacuum was that this eliminated heat loss by circulation of the gas within the bulb and thereby increased the efficiency. On the other hand, further investigation of the effects of gases on tungsten showed that the presence of an inert gas cut down the blackening of the bulb. Was it possible that gas would permit a sufficient rise in filament temperature so that the relative increase in light emission would more than compensate for the new convection heat loss. The laws of heat flow in gases, which had been worked out in the course of the same research, were applied, and the answer was yes, but only for filaments of an impossibly large diameter so far as common use was concerned. The difficulty could be solved by coiling the filament, for then its electrical characteristics would be those of the fine wire while its heat losses would be those of a heavy one. An ingenious solution, which, however, required a so-called nonsag filament, one which would retain its coiled shape throughout its life. Here was a metallurgical problem again. Its solution involved another about-face in the constitution of the filament. Originally of tungsten, it had been found necessary to introduce thoria if the filament was not to disintegrate on alternating current. Now the purity of the wire had to be reestablished, but a revised heat and mechanical treatment was found which developed long interlocking crystals in the wire.

This account shows you a small section of science at work, exhibiting its approach, its needs, its ramifications, its power and its consequences. The approach is that of full knowledge of what has been discovered before, and acknowledged ignorance of the new things which must be found out.

Its needs of specialized knowledge in research and development can only be filled by having a staff of specialists available for work and consultation. And each scientific and engineering advance creates its own experts in its wake.

Each contributing specialized field brings its own materials and equipment to the new task. Machine tools, microscopes, meters, thermocouples, gauges, power supplies and so on are among them.

Its consequences are the creation of new satisfactions for human needs and desires with an expenditure of less effort per unit produced.

Its ramifications arise from the unsuspected relations and undreamed-of effects that are discovered. It is these which will be most fruitful in the future. One such effect has already been mentioned, that of a gas cutting down the rate of evaporation of the filament. The incandescent lamp research also elucidated another effect whose importance was destined to equal that of the light.

Edison had found in his lamps that an electric current would flow in the vacuum between the hot filament and another electrode. Langmuir proved that a similar current flow in tungsten filament lamps was due to electrons

evaporated continually out of the hot tungsten. There was, seemingly, an opportunity for considerable electric current, carried by the electrons, to flow between the ends of the filament where the voltage difference was greatest. This phenomenon was the doorway to radio. The key to the door was the answer to the question: What limits the electron flow from a hot filament and keeps it very small even though the temperature is raised? The answer is: The mutual repulsion of the electrons whereby those which are traversing the vacuum retard the escape of their successors from the hot metal. Not only radio, but the modern telephone system, and most of our methods of automatic control and recording are corollaries of the answer to that question.

What we have seen in our small sample of scientific endeavor is typical. It shows us that large social and economic resources must be available to create, gather together and hold the technical personnel and the physical plant. These resources are necessary at each level of progress, namely in fundamental research, in the development of a product, in its production and in the further exploitation of the experience gained.

The result is that science itself is a potent factor in the development of big business. There are other factors, to be sure, chief among which I should put the advantage of monopoly in a capitalist system. But the logic of scientific progress points to large highly integrated units of development and production quite apart from the economic organization of society. The day of the individual researcher is past. The pattern now is one of cooperative interlocking effort. This is as true in medicine as in television. If you want insulin and sulfanilimide you will have to accept big industry, too.

I have been at some pains to contrast the Aristotelian approach as exemplified by Euclid with the scientific method as illustrated in the electric light. I have tried to bring out that the self-evident nature of postulates is no guarantee either of their validity or the range within which they are valid, but that the ultimate arbiter is nature herself. Time and again nature has brought us up short with the proof that she is infinitely more versatile and ingenious than even the mind of a genius. I think we have learned this lesson with regard to the physical world. Galileo, Copernicus, Einstein and Planck are all names associated with revolutions in scientific thought. The associated advances only had to be revolutions because this lesson had not been learned.

This lesson is still unlearned, however, with regard to the world of human affairs. In economics, we have, I think, discarded the Economic Man, and we do not hear so much about the Law of Diminishing Returns. But the authorities still appeal to the Law of Supply and Demand. Demand, how expressed? By cash bid, by promise to pay, by petition or by elemental human needs? Demand for what? Opium, gin, a decent standard of income, food, coming-out parties or jobs? Supply—how adequate in volume and quality, delivered where and how long hence? "No," our Aristotelian economist may say, "the law is more general than you would imply. Demand means *effective* demand, and certainly there are limitations on supply set by the economic and social circumstances of the time and locality." Perhaps this is a poor defense, but in my brief excursion into economic theory I found no other. Let us incorporate the explanation into the statement of the law. Here is what we have: If a demand is effective in augmenting the supply, then the supply will increase, but some demands can not effect an increase because of circumstances. Does this say anything at all, let alone express a funda-

mental economic relation? Hadn't we better forget it and start fresh with a detailed analysis of all the controlling factors?

We are hearing much about the stimulation of private enterprise. How "private" are enterprises whose owners number from the thousands into the millions? I hardly believe that the users of the term refer to the comparatively small number who own the bulk of the stock or to the increasing control by the managing personnel. How "private" is a corporation which controls a substantial portion of the transportation facilities, which have become a necessary part of our life, whether rail, air, water or automotive? How "private" is a corporation which either openly or secretly or in both ways uses its concentrated resources to influence legislation? And the word "stimulate" could bear a little historical and factual examination.

Examples could be multiplied. I cite one more. It is common practice to begin a socio-economic discussion with the premise: All of us are divided into three parts, capital, labor and the public. Apparently the white-collar middle class must be the public because we are classed neither with capital nor labor though we do earn our living. And aren't the capitalist and the worker part of the public? If wages are increased too much (what is "too much" relative to actual union demands?) then the public, we are told, won't be able to buy the product. Are these analysts really afraid that the increase in wages will be banked, as is happening to so much income at the present time? No valid conclusions can flow from this stereotyped erroneous subdivision of the population which is incomplete in its enumeration and overlooks essential interrelations.

I believe that we are making some progress in the direction of science in human relations. More and more factual studies from which limited conclusions can be drawn are being made. But we are advancing far too slowly. The advance is slow because we are half blind to the possibility of applying science and also because of active opposition. It is too slow because in recent years our social maladjustments have been accumulating more rapidly than our power to deal with them.

An outstanding characteristic of the world that science has created is that the individual no longer controls the elemental production processes. The processes have themselves become too intricate and subdivided. The truck gardener probably comes closest to control, but he is absolutely dependent on gasoline, electricity, automobiles and the textile industry. At a more primitive stage each of us had a less perfect but a direct control over our sources of supply and means of fabrication. In perfecting our control of nature, however, to increase her bounty and mitigate her severity we have developed a new system of human relations whose essential functioning is as unknown to us now as were the relations between the earth, sun, moon, planets and stars before Copernicus and Kepler.

In both cases the existing knowledge had been sufficient for many purposes; in both cases powerful forces were arrayed against the logic of the facts which were accumulating. The essential difference in the two situations is this: The astronomical makeshifts could have been elaborated indefinitely. There was no critical urgency in the need for the simpler navigation methods which the Copernican view made possible. On the other hand, the maladjustments in our social arrangements have already resulted in positive retrogression in large sections of modern civilization. In our own country the expedients to which we have been temporarily forced appear to be increasingly necessary and at the same time increasingly impossible to maintain.

Is there any consensus of opinion that the gathering and correlation of social and economic facts should be vastly expanded? Are scientists more inclined than others to ask for this extension of a fruitful technique? In England some of them have developed a social awareness that has not been exhibited in this country. Here the scientist reserves his independence of thought and the inquiring attitude for his special field. As a scientist he is right-handed and as a citizen he is left-handed, and he lets not his right hand know what his left hand doeth.

One excuse that lacks either candor or intelligence is that experimentation is an essential part of the scientific method, and you can not experiment with human beings on a social scale.

The answer to this is twofold. We do experiment. Russia is one example, the settlement of Alaska another. Free public education, every educational innovation and every change in a social institution from the Montessori method to the TVA and socialized medicine is an experiment.

Second, many sciences do not find it possible to experiment. Astronomers, for instance. The one astronomical experiment I know of was that of Joshua, who made the sun stand still, and, scientifically speaking, it was a failure because no one has been able to repeat it. Geology is a science, but what geologist has ever made a fossil in the laboratory?

In somewhat similar vein is the belief that there is an essential difference between the relations of individualistic, thinking, emotional and willful human beings and those subsisting in the lower orders of life, and that this difference transcends the application of the scientific method. This is reminiscent of a conviction that has been widely held that the chemistry of life-processes was essentially different from the chemistry of the test-tube. The laboratory synthesis of urea in 1828 effectively disposed of that view. But let us discuss the newer version.

The present threat to our culture does not arise from factors which are unique from person to person. It arises from more or less universal characteristics in the interrelations between man and his social institutions. There are certainly variations from the norm which differ in magnitude; and some of these variations may themselves be large enough and common enough to be of significance. But scientific method is prepared for this contingency just as mathematics was ready with the $\sqrt{-1}$. In the study of gases physics has synthesized the individualistic behavior of atoms to derive the gas laws. A whole branch of the science is devoted to problems akin to this. It is called statistical mechanics.

As a matter of fact there is an existing social institution which within the limitations of its function applies statistics to a highly variable contingency of human life—namely, death. It is worth noting that the chief threat to life insurance in the last thirty years has come not from the additional mortality of the First World War but from the developing economic instability of our society itself. The variations from the average are also recognized in this institution, because, among others, those afflicted with syphilis, tuberculosis or diabetes can not avail themselves of it.

But more cogent than these arguments is the fact that social studies have been made and have established important relations within our culture which could only be speculated about before.

I do not assert the imperative necessity for our culture to extend its use of science without realizing that the opposition to this step is tremendous. On the whole it is probable that science on its traditional ground has had an easier time of it, even though it has, on occa-

sion, trod on tender but powerful ecclesiastical toes. In its application to social problems, however, it finds two enemies, those who fear that their moral preconceptions may not square with the implications of the facts and those whose economic interests and social prestige are threatened. The latter can command powerful weapons, which have been created by science itself, to combat its extension and nullify its power. This is a contingency which lies outside the power of science to deal with. Stars, triangles, atoms and fruit-flies do not talk back, but those whose social functions are obsolete do this, and more. The situation calls for a greater awareness of the threat to our culture and the will to get the facts without which a solution is impossible.

# THE GROWTH OF AN IDEA

By Dr. CARL E. SEASHORE

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THE "idea" in this case is the conviction that *musical talent is subject to scientific analysis and can be measured.* Some forty odd years ago a colleague in the university faculty who was a very fine violinist kept boasting what a fine musical ear he had. One day I rose to the occasion and said, "Van, I'll find out how good your ear is by measuring it." The challenge was accepted, I devised the apparatus, made the measurement and found that he could hear a difference of about one seventieth of a tone. This was an objective fact, specific and verifiable.

At that time it was a new idea that one could measure specific personal traits quantitatively. Terms like differential psychology, individual differences, talent chart, I.Q., vocational guidance, educational measurements, statistical methods, applied psychology, the psychology of music and many other facts about the recognition of the individual and his personal equation which now loom up so large were at that time practically unknown.

It is my purpose here to illustrate in a somewhat intimate and personal way the normal growth of laboratory research from a germinating idea as it can be traced in the Iowa laboratory. My treatment must, of necessity, take the form of evaluation and bold touches in highlights rather than the amassing of descriptive facts and details.

Van's sense of pitch had been measured, but what did it mean? To answer that question in part, I measured myself, and, to the surprise of both of us, I found that my ear was as sensitive as his. But this did not leave us much wiser, although on more nearly equal terms. So I measured the sense of pitch in a class of thirty students and found that they varied from the ability to hear approximately one hundredth of a tone to the inability to hear a difference of one-half tone. This then was the beginning of a new scale of interpretation. Van and I could compare ourselves with others. This measurement was repeated upon hundreds of adults, and reliable norms of distribution of capacity were established.

The question then arose: What is the cause of these very large differences? When we found that of two normal persons, one may be more than one hundred times as keen as the other in pitch discrimination and that this is relatively fixed, our first resort was to refer it to differences of intelligence or powers of observation; but, to our astonishment,

we found that there was no significant correlation between the sense of pitch and intelligence. Indeed, the student who made the poorest record in the sense of pitch in my original series was one of the brightest of the class and is now a member of the faculty of the University of Iowa.

The next hypothesis was that it might be due to training. To verify this, we first correlated the records on the sense of pitch with the records on the amount of training in music that each student had had and found that there was no significant relationship. That is, a keen sense of pitch is not due to training. To verify this startling find we took all the children in an eighth-grade room and gave them the most intensive training possible in this specific act daily for a month, and we found that the distribution and degree of ability in this task remained practically the same at the end of the training as it had been before training.

At that time it was believed, on the basis of certain experimental evidence, that pitch develops with the age of the child, but our eighth-grade children had done as well as the university students. This was contrary to musical and educational theory at that time. We therefore established age norms from ten years old and up and found that aside from development in the capacity to apply themselves to a task of this kind, there was no evidence of improvement in the sense of pitch with age. In spite of the fact that normal persons show astonishingly large individual differences in capacity for pitch discrimination, it is found that this capacity does not vary consistently with age, intelligence or training.

Applying this to the evaluation of our first measurement upon Van and myself, we may say that our sense of pitch falls within the highest two per cent. in a normal community; that it is probably a fixed, inborn talent which is relatively independent of general intelligence and age; and that it improves with musical training only in the same sense that the acuity of vision improves with training in art production or appreciation. It must be clear to any one that all these psychological facts are of extraordinary educational, social, musical and economic significance.

These first and radical findings launched us upon a program for an intensive study of the sense of pitch which is still in progress and has borne most gratifying fruit in our knowledge about this type of individual differences as involving principles of pure psychology, and applications of this knowledge in anthropology, genetic psychology, heredity, music and education. Through this, our concept of a musical talent has been enriched and vitalized and we have discovered its basic role in countless situations in daily life, art and industry, where its presence had not been recognized before.

It was natural, then, that we should ask: What other talents may be analogous to this? This led us into an investigation of a number of recognizable units in the complex forms of pitch hearing, as in the hearing of consonance, harmony, melody and various types of modulations of pitch; and this led to the beginning of what we may call "the psychology of pitch."

We then made an objective analysis of tone to determine the characteristics of the sound wave and found that there are four and only four; namely, frequency, amplitude, duration and wave form. For the hearing of each of these characteristics of tone we recognized the necessity of a specific capacity; namely, the sense of pitch, the sense of loudness, the sense of time and the sense of timbre. These cover the tonal, the dynamic, the temporal and the qualitative attributes of sound.

We then entered upon a program of

measurement and analysis of each of these on the pattern of the studies on pitch and followed these four basic factors into their variants, combinations and interrelations in the actual musical situation. This gave us a sound basis for the analysis of musical hearing.

For each capacity for musical hearing, both simple and complex forms, we must look for a corresponding capacity for performance or tone production. This gave us a classification of the motor capacities necessary for the control of sound in a musical performance.

This parallel classification of sensory and motor processes based upon the four characteristics of the sound wave was found to carry through the higher mental processes of memory and imagination, the higher cognitive processes of conception, judgment and reasoning, and the various aspects of feeling and emotion and all types of musical action. That is, when we remember a musical selection, imagine it, think and reason about it, and analyze our musical feelings and all types of musical action, it is always in terms of one or more of these four factors or their derivatives. They constitute the content to which the music gives form. All musical creation, as in composition, is but the artistic arrangement of these four elements in musical content. All appreciation of music is in these terms. All mastery of musical performance may be expressed in these terms.

Recognition of this type of classification constituted a preliminary survey of our field for investigation and made elements of musical experience and behavior tangible for measurement and analysis in the laboratory. Thus we found ourselves in a most fascinating new field with opportunities for blazing trails in hundreds of directions theretofore unexplored. This new field we now call "psychology of music." As the field broadened, we found ourselves constantly drawing upon and contributing to general principles of psychology and were thrown into cooperation with allied and underlying sciences on a large scale.

It was gratifying to find that this subject could be treated either as pure or applied psychology, that the applied aspects might be treated experimentally in the same manner as problems of pure psychology and that the interests of pure psychology could be served in as clear and unhampered manner when a practical application was in mind as when it was not. We found ourselves constantly drawing upon and contributing to general principles of psychology and had to branch out in cooperation with allied and underlying sciences. Fascinated by the magnitude and the immediate yield in this field of the science of sound, the staff and equipment of the laboratory was for many years concentrated upon this objective at a sacrifice of many other possible laboratory interests.

At that time there were no other laboratories equipped for this operation; at every turn we were blazing new trails. The matter of equipment was and is yet a constant problem calling for ingenuity, invention and facilities for the building of instruments. The opening up of a new field of investigation calls for new types of equipment, means of measuring every aspect of sound, means for producing all musically significant types of sound, means for the analysis of each and every feature of the sound and means for the complete phonophotographic record of any musical performance. This represents a bewildering nest of complicated instruments. Fortunately, the psychology of music was really made possible by the extraordinary progress of invention and provision of instruments which came in through the commercially profitable and scientifically intriguing developments in radio engineering. Without these, the

best contributions of any university laboratory would have been insignificant.

But instruments are mere tools. They must be designed for specific problems. We could not shoot at the blue sky of all the psychology of music, and therefore we had to pick specific aspects which from time to time became tangible and significant. Of these, there was an abundance, all bearing directly or indirectly on the problem of laying scientific foundations for some phase of the art of music. One of the constant problems is the experimental definition of terms. Timbre, for example, was but little more than a French name. A permanent and verifiable definition had to be determined by experiment, and the loose musical jargon hovering around that concept had to be scrapped in favor of the experimentally determined definition of the word. This was the first step in the assignment of an understandable and vital function to timbre in music. Prevailing theories had to be submitted to verification, as in the case of the laws of harmony, action of the vocal cords, musical phrasing and scales. Our extensive publications of researches on such specific issues of musical experience and behavior tell an interesting story.

But the effort to deal with any single problem of musical sounds at once took us into allied fields, such as the perennial problems of heredity and environment and the science of genetics, the physics of sound, the physiology of hearing, the endocrine basis for emotion and electrophysiology of nervous control. Since the object of the investigation was music, there had to be constant rapport with current leaders in musical theory, education and criticism. The barriers among such fields have broken down, and in the last fifty years progress has been made by leaps and bounds. As a result of the recent development in acoustics in the interests of radio and all other forms of sound engineering, we had in most cases only to share and help to harvest the common findings.

Out of the science built from all these sources, new applied sciences have gradually emerged. Mastery of the measurement of musical talents took us into the midst of a practical field of musical education. As the measurement of musical talents became recognized as a scientific approach to the problem of individual differences, differential psychology took many new turns. Refinement of mental measurement in hearing led to special fields of mental testing. When we went into the World War, we had to answer the question: What can psychology contribute? and some notable contributions came from the psychology of music in the location of U-boats and the selection of personnel. Musical anthropology took a new scientific turn. All we had learned in the study of musical sounds had its parallel and counterpart in speech, and hence arose the psychology of speech. While each of the arts has its medium, they all have certain principles, talents and goals in common. In recognition of this, there grew up in the laboratory a separate division of the psychology of graphic and plastic arts. Musical anthropology which had previously been loose observation turned experimental. As we learned to record and interpret musical performance, problems arose in regard to what is possible and what is good in musical performance. And through the years of accumulation of musical terminology, classification and experimental theory, we found ourselves laying foundations for a scientific musical esthetics. None of these problems has been solved, but the mere naming gives us some conception of the richness of possibilities of a new field, such as that of the psychology of music.

While much of the overhead work in the Iowa laboratory has been my happy

lot, the accomplishments in the whole program must be accredited to the large body of students and colleagues in the department who have shared in the building up of the laboratory. It must be clearly understood that the progress in large as we now see it is not the work of a single laboratory or the fruitage of a single idea but rather the integrated findings of many interlocking sciences, of many laboratories in each science and often of many individuals in the laboratory. May I add also that the type of specialization here involved has furnished the workers in the field an excellent opportunity for broadening the scientific horizon and extending the vision into approaches to the science of the art of music.

Such is a sort of privileged retrospect under the license for reminiscence extended to an old man who has lived through much of it. Perhaps the picture is overdrawn. However, every statement is subject to verification. I have tried to see the development in relief, especially as it germinated and rose into the structure of a scientific family tree in rich branching with foliage and fruiting. The germinating idea was that "it can be done"; musical talents can be measured. There was no sudden leap from the sprouting of this idea up to the present level of achievements; but progress was made by continuous logical and tireless work going by natural steps from one stage to another. The germinating idea was not exactly new; it was simply vitalized and thrown into line with parallel developments. Perhaps the most all-impressive contribution that has come out of this entire development is the revelation of how little we know of such a "knowable" subject.

# CAN THE UNITED STATES HAVE BUTTER AND GUNS?

By ALFRED W. BOOTH

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THE slogan, "Guns for Butter," which epitomized the German campaign to re-arm, also powerfully expresses the place of vegetable and animal fats and oils in the modern industrial economy, and more especially, in the economies of warring nations. Numerous tales and incidents reported in our daily papers are constantly emphasizing and re-emphasizing the strategic importance of fats and oils. Most of us have read stories about the Germans limiting the number of baths so that soap may be saved. We are all aware that Germany is raiding Denmark for its butter, and that margarine is being strictly rationed in Britain. Occasionally we hear of such desperate measures as that taken by France in sending a portion of its fleet to Dakar to escort back freighters loaded with vegetable oils. Yet few people realize that our own country would also be faced by an acute problem if our imports of vegetable oils and fats were cut off.

The annual consumption of animal and vegetable oils and fats in the United States is over 71 pounds per capita, a figure which far outstrips that of any other large nation. Certainly, in view of this, animal and vegetable oils and fats must be considered as we plan for national defense or for any economic, political or military emer-

gency which might arise. Since the supply of animal fats and oils produced in the United States is normally adequate, the problems associated with vegetable oils and fats will be stressed in this discussion.

Perhaps the importance of vegetable oils and fats in our everyday life, in our industrial life and in our projected preparedness program may best be emphasized by listing some of the products which, in whole or in part, are obtained from them. These run the gamut from the oil in which our sardines are packed to the high-grade lubricating grease used in airplanes, from the paint on our cars to the candle burning in a backwoods home, and from the linoleum on our kitchen floors to the shampoo we use on our hair. In listing these products in the order of their quantitative importance, first place is occupied by shortening, vegetable fats having taken over that function from lard (Fig. 1). In second place is soap, about one half of which is made from vegetable oils and fats. Nearly all the best quality soaps used for personal purposes are manufactured from vegetable oils and fats. Next in order is oleomargarine, followed by other edible oils (salad oils, etc.), and paints and varnishes. Less important from the standpoint of amount consumed, but of great importance because of their strategic values, are such products as linoleum, oil cloth, printing inks, high-grade lubricants, and especially glycerine and nitroglycerine, from which explosives are manufactured. Vegetable oil is also utilized for quenching steel, as a flux in the tin-plating process, and as a base for dyes.

Vegetable oils and fats are obtained from a great variety of plants belonging to a number of plant orders. Usually the seed is the source of the oil, although in some cases the oil is obtained from the fleshy pulp of the fruit. In the case of the oil palm the oil is obtained from both the pulp and the kernel. Plant oils or fats are classified mainly according to their drying or edible qualities or according to their consistency. Drying oils are those which, upon exposure to the air, have their exposed surfaces oxidized into a leathery skin, and are thus invaluable for the production of paints and varnishes. Some oils are considered semi-drying, that is, with but little processing can be made into drying oils. Soybean oil may be cited as an example of a semi-drying oil. Edible oils are those which are most palatable, which have high food value and which usually are non-drying. A wide variation in classification is possible since certain oils change from the edible to the non-edible class, or from the drying to the non-drying class, as prices fluctuate or as new processes for treating them are developed.

The basic difference between an oil and a fat lies in their consistency at normal temperatures. Usually the original plant product is an oil, but by the process of hydrogenation this oil can be changed into a fat. It was the perfecting of this process of hydrogenation about forty years ago that led to the introduction of oleomargarine as a butter substitute. Since then vegetable oils have been more than co-equal to animal oils in world consumption and trade. Even in the United States, where animal oils and fats are still significant, the average consumption, exclusive of butter, is only 23 pounds per person as compared to a vegetable oils and fats consumption of over 30 pounds per person.

Almost three and one half billion pounds of vegetable oils and fats were consumed in the factories of the United States in 1938. Just how the present rearmament program will affect us is problematical, but no doubt an increase in consumption may be expected. Approximately 46.5 per cent. of the vegetable oil and fat consumed in this coun-

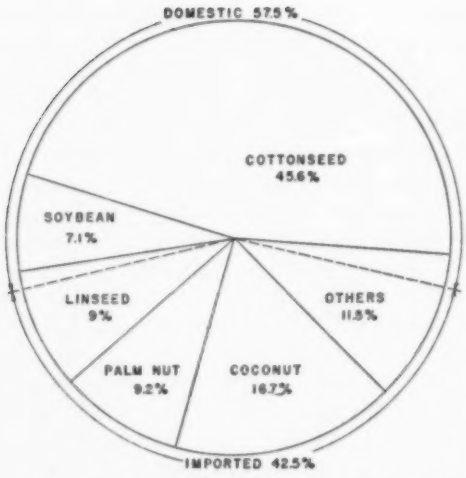


FIG. 1. PRIMARY OILS AND FATS CONSUMED IN U. S. FACTORIES—1938. AN ANALYSIS OF THE SOURCES OF UNITED STATES VEGETABLE OILS AND FATS.

try was derived from cotton seeds, 16.7 per cent. was derived from coconuts, 9.2 per cent. from oil palm nuts, 9 per cent. from flax seeds, and 7.1 per cent. from soybeans (Fig. 2). The remaining 11 per cent. of our vegetable oil and fat was derived from tung tree nuts, corn, peanuts, rape seeds, perilla seeds, castor beans, babassu palm nuts and a number of other oil-producing species. Especially to be noted in this list are coconuts, oil palm nuts, flax seeds, and among the minor sources, tung tree nuts, castor beans and babassu palm nuts, since our entire supplies of the oils and fats derived from these plants are imported. Surprisingly enough, the United States also imports small quantities of cotton seed, corn and peanut oil. Of the three and one half billion pounds of vegetable oils and fats consumed in our factories in 1938, almost one half, or about one and one half billion pounds, was imported. These oils and fats come to us principally from the Philippine Islands, the Netherland East Indies, China, West Africa, Argentina, Brazil and Japan. The fact that we are now so dependent upon outside sources for vegetable oils and fats must be considered in charting the course of American foreign diplomacy and agricultural economy.

Thus far, despite the present wars, our vegetable oil trade has not been seriously affected. Our African supplies have been partially cut off, but since they were already becoming less significant with the shift of oil palm production to Sumatra, no shortages have been created. Our imports of tung oil and, secondarily, peanut oil, from China have also been curtailed. However, this curtailment has not been too serious, since Hong Kong is still an open port and even the Japanese are not too unwilling to act as middlemen. The only result of the European war thus far has been some allocation of trade because certain oil-bearing raw materials which formerly went to England, Belgium and the Netherlands for processing are now being shipped directly to the United States.

In planning for future supplies of vegetable oils and fats, particular attention must be paid to Southeastern Asia and the adjacent East Indies. Over two thirds of our imports, or almost one third of all the vegetable oils and fats consumed in this country, come from that part of the world. Rubber and tin are

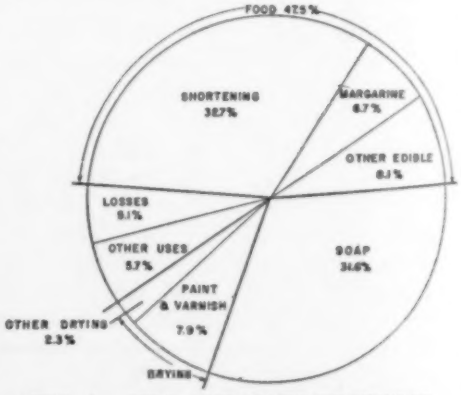


FIG. 2. OILS AND FATS PRODUCTS PRODUCED IN U. S. FACTORIES—1938. AN ANALYSIS OF THE USES OF VEGETABLE OILS AND FATS IN THE UNITED STATES.

not the only raw materials which should influence the course of our diplomacy in the Far East. Japanese aggression could become especially serious if the Philippines, from which we obtain 100 per cent. of our coconut oil, were cut off from trade with us.

Two countries in South America contribute substantial amounts of vegetable oils and fats to the United States. From Argentina we obtain about two thirds of our linseed, and from Brazil we receive cotton, peanut, castor and babassu oil. Several other countries in South and Central America are potential sources of oil. If Southeastern Asia and the East Indies were cut off from the United States trade, we should have to depend upon Latin America for the oils and fats of tropical plants. This potentiality of our Southern neighbors might well be utilized in our present "hemispherical solidarity" campaign, since any effort on our part toward encouraging production of vegetable oils and fats in South America would be of mutual benefit. Admittedly, it would take a number of years to establish this trade, but if we are preparing for any eventuality, it might be well for us to start now.

The question finally arises: How would this nation fare if all these sources of vegetable oils and fats were cut off from us by war or blockade? The immediate result, especially if this severance were sudden, would be an acute and dangerous shortage for an indeterminate period. The ultimate result would depend upon our ability to make shifts in our agricultural economy, to develop substitutes and to make technological changes. All this presupposes that we would not be content to lower our living standards to those which exist on Continental Europe.

Let us first consider our ability to increase our domestic production of vegetable oils and fats. Physical conditions, chiefly climatic, make it impossible for us to grow the coconut, oil and babassu palms, which, together, now supply us with about one fourth of all our

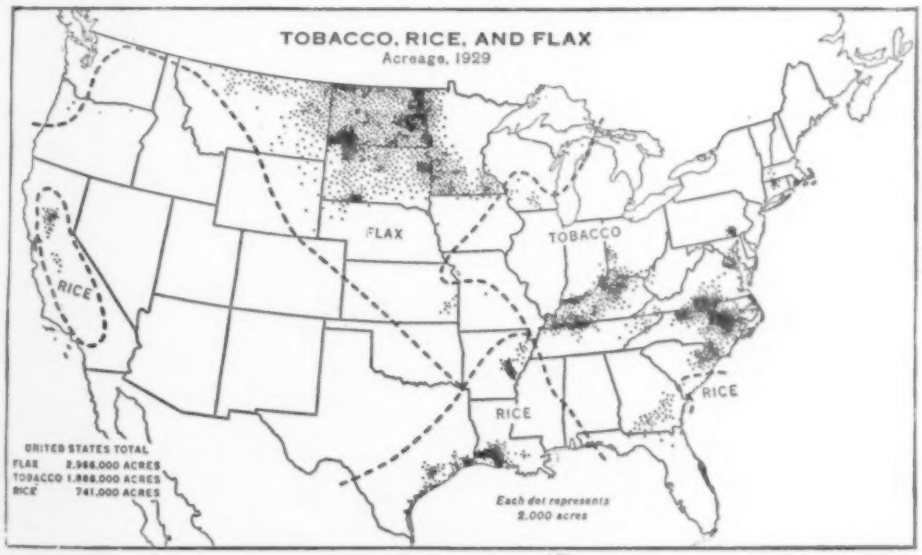


FIG. 3. FLAX ACREAGE, 1929*

THE SPRING WHEAT BELT IS OUR GREAT PRODUCING AREA.

* Figures 3, 4, 5 and 6, are printed through the courtesy of the U. S. Department of Agriculture.

vegetable oils and fats. All other significant oil-producing plants, cotton, flax, tung, soybean, corn, castor bean, etc., can be raised successfully in this country. Despite this, we now import vegetable oils and fats derived from all except one of the plants just listed. Thus, any campaign for self-sufficiency would, perforce, have two objectives: first, to become independent of outside sources for the oils and fats of the plants we can raise; and, second, by utilizing native plants, to balance the deficit which would exist because we can not grow oil-producing palm trees.

The leading native source of vegetable oil is cottonseed. Better methods of expression and complete use of all our seed would easily make up for the small amount of cottonseed oil which is imported. However, under existing cotton prices, a great extension of acreage, sufficient to make up our deficit, seems improbable. It might be stated at this point that a variety of cotton which produces little lint and a seed which has a high oil content has already been developed. However, to make this type of plant profitable, oil prices would have to rise considerably.

Next on the list of oil-producing plants which are grown in the United States is flax, whose seed (linseed) is the leading source of drying oil. At present we supply about one third of our need. Most of this comes from the grain lands of the Dakotas (Fig. 3). In view of our large annual wheat surplus, it would seem that the simplest solution to the problem would be to turn wheat acreage over to flax. However, flax is a difficult plant to cultivate and harvest, and, in addition, is much more subject to losses through vagaries of weather, weed growth, insect pests and blight than is wheat, so that even now, in spite of high protective tariffs, it is not a popular crop. Perhaps some form of government crop insurance to make it a less speculative crop would encourage increased production. Some small subsidization might also be necessary. If these measures were instituted, flax acreage might be increased to about the necessary 4,000,000 and self-suffi-

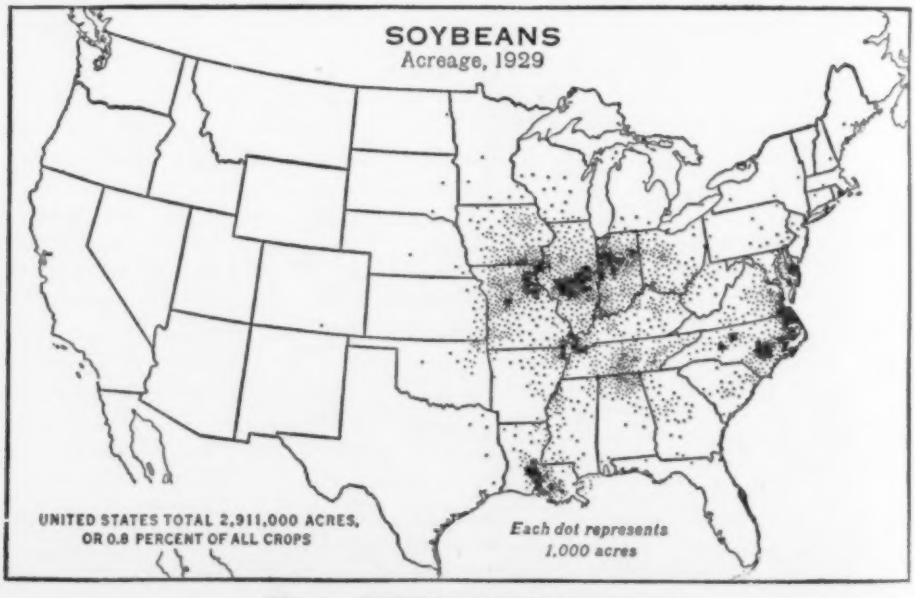


FIG. 4. SOYBEAN ACREAGE, 1929

SOYBEANS ARE PRODUCED IN OUR CORN BELT AND MANY AREAS IN THE SOUTH.

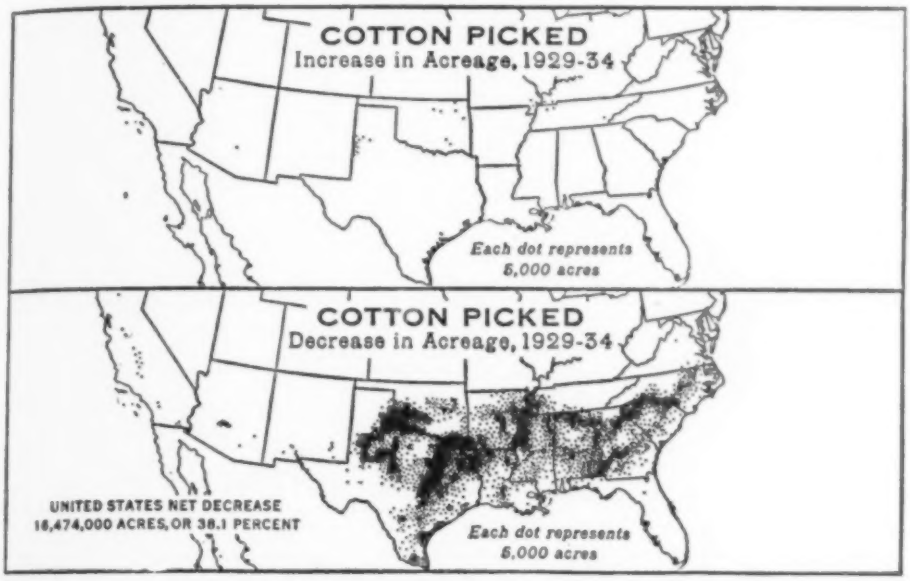


FIG. 5. CHANGE IN COTTON ACREAGE, 1929–1934

PERHAPS SOME OF THE LAND TAKEN OUT OF COTTON PRODUCTION MIGHT BE DEVOTED TO OIL-PRODUCING CROPS.

ciency be attained. The recent development of strains of flax producing good oil seed and fiber suitable for linen (also a need in this country) will probably be an added incentive toward more flax production.

A secondary source of drying oil is the tung tree. The United States imports

FIG. 6. PEANUT ACREAGE, 1929

PEANUTS ARE AN EXCELLENT SOURCE OF EDIBLE OIL.

85 per cent. of its need of this important paint, lacquer and waterproofing material from China. Tung oil also enters into the manufacture of such products as linoleum, oil cloth, brake lining and inks. Since the Chinese supply was uncertain even in pre-war years, tung tree orchards were started in our Far South (southern Mississippi, Alabama, Georgia and northern Florida) about forty years ago. Today, the lessons of production having been learned, the United States is well on the road to self-sufficiency, a goal which might well be reached in the next ten or fifteen years if the present rate of increase is maintained. For the time being, however, we are still dependent upon China.

Since both drying and edible oil can be obtained from the soybean, that source of oil has unique value. So great are the potentialities of the United States for soybean production that we already supply all our own soybean oil needs with ease. Large areas in the Corn Belt are almost ideal for its production. The great surplus of corn in recent years would seem to indicate that this corn land could easily, and even more profitably, be turned to the soybean, which also has the advantage of being a leguminous crop. Another large region of the United States which is suitable for soybean production is the South, where it is now grown mainly as a forage crop (Fig. 4). The 16 million acre reduction in cotton acreage in this country in recent years has certainly made land available for raising soybeans (Fig. 5). If soybean production could be tripled, at least one third of our deficit of vegetable oils and fats could be overcome.

Two other crops which might be produced in increasing amounts in our South are the peanut (Fig. 6) and castor bean. Peanut oil is an excellent edible oil and could well take the place of either the olive or cottonseed as a source of salad oils and in margarine production. By increasing our acreage only one fourth we could become self-sufficient. Even a twofold or threefold acreage increase should not be difficult. Castor bean oil is an important source of lubricants, particularly for use in aviation, and thus has special strategic importance. Our need could easily be supplied by domestic production.

The case of corn as a source of vegetable oil is a puzzling one. This country has always produced a tremendous quantity of corn, very little of which, however, is utilized as a source of oil. During the first World War corn oil entered the market to make up for the deficiency in fats and oils which existed at that time. Admittedly, this oil was for a while inferior to other types, but was very soon brought to a desirable quality standard. Yet after the war, it almost dropped out of sight in spite of extensive advertising campaigns. Perhaps another effort to educate the American housewife to its desirability would be the most effective wedge toward its increased use. Corn oil, along with soybean and peanut oil, might be the answer to the problem of making this country independent in its supply of edible oils and fats.

Although it is physically possible for the United States to become free of foreign sources of vegetable oils and fats, there are a number of "ifs" and "buts" which would make the freeing process a long-time affair. Basically, most of the difficulties are centered in the fact that the education of both producer and consumer would require years to complete. It is also true that the farmer has always been conservative in introducing new crops or making sharp changes in his cropping system. Though these changes may be brought about more quickly by bounties, subsidies, or tariffs, all these measures would result in increased prices, which, in turn, might result in a

decreased demand. Such a condition would be incompatible with our goal of butter and guns.

To tide us over a transitional period as smoothly as possible, substitutes for vegetable oils and fats would have to be utilized. Perhaps the best of these substitutes is animal oils and fats of which, fortunately, the United States produces a great surplus. Each year, until the present European war, this country exported over a billion pounds of lard. Much of this is now accumulating in warehouses.

There are a number of objections to permanently substituting animal oils and fats for vegetable oils and fats. Briefly, these are: their non-drying quality; their lower desirability for edible purposes; and their undesirability for soap-making purposes. If our acreage of oil-producing plants were gradually increased, our output of animal oils and fats would automatically decrease at a greater rate, since the acreage of forage crops would become smaller. Thus the present problem of over-production of animal oils and fats would also be partially solved. It should be emphasized, however, that it would be our animal oils and fats which would best serve to carry us through any period of shortage.

Other possible substitutes for vegetable fats and oils are mineral oils and chemically produced materials which perform the same duties as oils and fats. Even though mineral oils are a potential raw material source of certain oils and fats which could take the place of vegetable oils and fats (an artificial tung oil has already been perfected), the uncertainty of future supplies and their importance in a war economy makes them unlikely substitutes. In the last few years chemically produced detergents, soap substitutes containing no oils or fats, have received considerable attention and may prove to be a valuable asset, since soap-making consumes 20 per cent. of our vegetable oils and fats. At the present time, small amounts of detergents are used as soap substitutes. Here again, the time factor becomes an element to be considered, for the construction and installation of the proper apparatus and machinery can not be an overnight process.

It thus appears that, if, in this country, we expect to have and to continue to have our guns along with our butter, we must be prepared for certain eventualities. At present, the most serious threat upon our supplies of vegetable oils and fats lies in possible Japanese aggression in the Far East. This threat would be especially serious if the Philippines were lost, because it would certainly be followed by a period of acute shortage and technological change. If we did not prevent such an eventuality, our best opportunity to prepare for its consequences would lie in the development of South American sources, and some changes in domestic production. Of course, even the present or projected South American supply could be cut off, for example, by political unrest or by German economic penetration. Unless we are prepared to go through a rather painful readjustment period of from five to ten years, we must either be ready to prevent certain eventualities or must begin to prepare now for complete national self-sufficiency in vegetable oils and fats.

# THE CREATIVE YEARS: MEDICINE, SURGERY AND CERTAIN RELATED FIELDS

By Dr. HARVEY C. LEHMAN

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DURING what years of their lives are pioneer thinkers in medicine, surgery and public sanitation most likely to make their greatest contributions to the advancement of their fields, advances which will be regarded by later generations as priceless boons to humanity? In previous articles[1] the fact has been emphasized that generalizations with reference to man's intellectual productivity at various chronological age levels are sometimes based upon one or a very few exceptional cases. Impressionistic judgments based upon so-called "illustrative cases" are frequently fallacious. The general picture of man's creativity at successive chronological age levels can not be obtained by the use of "illustrative cases," unless it is definitely known that the cited cases represent a well-selected sampling. Therefore, the critical student should always ascertain, if possible, whether the citations which are submitted as "proof" are really fair and typical and not outstanding exceptions.

Nor do means and medians yield a very informative picture of the relationship between chronological age and man's creativity. The creative years may be envisaged best not by reference to "illustrative cases" which may have been obtained by inadequate sampling or by the use of a simple numerical average, which may hide as much as it reveals, but rather by study of age-curves (or statistical distributions) which reveal the relative productivity of all age groups.

It is the present writer's thesis that many of the studies heretofore published have tended to present a distorted picture of man's creativity. These earlier studies have been honest, in so far as conclusions which are based upon very limited data can be honest, and they have been interesting. But they have been analogous to the lawyer's one-sided plea. Some writers, for example, have presented an apparently strong case for youth; others have made a special plea for the aged. When controversy rages, a middle position, though perhaps less interesting, is likely to be more tenable than is either extreme point of view.

Careful study of the relative productivity of the various age groups involves among other things: (1) isolation of the most important contributions, (2) identification of the contributors, (3) knowledge of when the contributions were made and (4) knowledge of the exact birth and the death dates of the contributors. With the foregoing information it becomes a routine task to ascertain for each age group the average number of contributions that should be placed to its credit. The resultant averages should reveal clearly the age groups that have been most productive. One exception to this last statement should be mentioned. It is quite impossible to know the amount of time that must often have elapsed between the birth of a great idea and its public announcement. Obviously, the date of announcing an invention or a discovery does not enable us to know the chronological age at which the contribution was actually made. We can know only that the contributions

[1] (*a*) H. C. Lehman, THE SCIENTIFIC MONTHLY, 43: 151–162, 1936. (*b*) J. B. Heidler and H. C. Lehman, *The English Journal* (College Edition), 155: 294–304, 1937. (*c*) H. C. Lehman, THE SCIENTIFIC MONTHLY, 45: 65–75, 1937. (*d*) H. C. Lehman, *The Research Quarterly*, 11: 3–19, 1938. (*e*) H. C. Lehman and D. W. Ingerham, THE SCIENTIFIC MONTHLY, 48: 431–443, 1939.

that are to be discussed herein occurred *not later* than the chronological age to which they are credited.

The problem of evaluation presents a second difficulty. How are the fruits of genius to be evaluated? Does any individual possess the technical knowledge requisite for identifying the most important contributions that have been made in the fields of medicine, surgery, sanitation and the like? Would it not be presumptuous for the layman to attempt to evaluate the contributions which have been made in these highly specialized fields? Fortunately, in many instances, the task of evaluation is one that has already been performed by unintentional collaborators—by specialists in the various fields of endeavor. In one sense the present study is therefore merely a by-product of previous studies that have been made by recognized experts, who published their evaluations under their own names and who therefore must have felt their professional responsibility for making just evaluations.

The utilization of appraisals that have been published by well-known experts is desirable for still another reason. It is probable that most of the present writer's unwitting collaborators made their appraisals without thinking at all about the problem of age differences. Evaluations thus made are all the more useful for the study of age differences in productivity, since they are likely to be impartial judgments in so far as the age factor is concerned.

For example, in a book entitled "The Fundamentals of Bacteriology"[2] Professor C. B. Morrey presents a chronology of the contributions which he regards as the foundation stones of the science of bacteriology. Morrey lists not only the contributions but also the names of the contributors and the years during which each of the various advances was either made or first published. With this essential information at hand, the present writer undertook the task of finding the birth and the death dates of the various contributors. Some of these dates were found easily, some were found with difficulty, and some of them could not be found at all. The fact that some of the birth and death dates are unrecorded suggests that brilliant achievements are not always recognized as such by an individual's contemporaries. If the noteworthy contributions had been appraised immediately at their true worth, surely the birth and the death dates of the contributors would have been recorded!

Fig. 1 presents the results obtained by study of Morrey's chronology, namely, the chronological ages at which 50 outstanding discoveries were made by 41 pioneers in the field of bacteriology. Since Fig. 1 presents the *average* number of contributions at each chronological age level, this figure makes proper allowance for the fact that more of the contributors were alive at the younger than at the older age levels. Thus, in obtaining the data set forth in Fig. 1, it was found that, at the age interval 35 to 39 inclusive, the average number of contributions from each individual was 0.050, whereas,

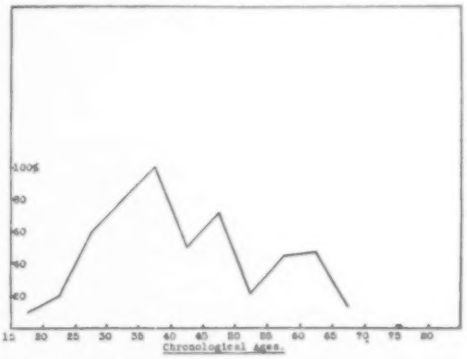


FIG. 1. AVERAGE NUMBER OF CONTRIBUTIONS TO BACTERIOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 41 INDIVIDUALS WHO MADE 50 CONTRIBUTIONS.

[2] C. B. Morrey, "The Fundamentals of Bacteriology." Third Edition. Philadelphia and New York: Lea and Febiger, 1923. Pp. xiii + 344. (See the chronology on bacteriology on pp. 33–36).

at the age interval 55 to 59 inclusive, the average had fallen to 0.022. In Fig. 1 the curve is so drawn as to be only 0.022/0.050 as high at ages 55 to 59 as at ages 35 to 39, thereby indicating that average productivity was only about two fifths as great at ages 55 to 59 as at ages 35 to 39.

If, regardless of the number of individuals that remained alive, the older age groups had contributed at the same average rate as did age group 35 to 39, the curve in Fig. 1 would have remained as high at the older age levels as it is at the age interval 35 to 39. Actually, the curve in Fig. 1 descends rather abruptly after attaining its peak at the age interval 35 to 39. Fig. 1 thus seems to reveal clearly and unmistakably that, in proportion to their numbers, men have made contributions to the science of bacteriology most frequently at ages 35 to 39, inclusive.

Let us see what has occurred in fields other than bacteriology. Fig. 2 presents the chronological ages at which 59 important works were first published by 54 noted physiologists. Data for the construction of Fig. 2 were obtained from Professor J. F. Fulton's "Selected Readings in the History of Physiology."[3]

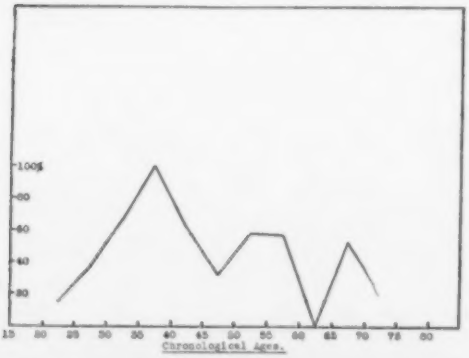


FIG. 2. AVERAGE NUMBER OF CONTRIBUTIONS TO PHYSIOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 54 INDIVIDUALS WHO MADE 59 CONTRIBUTIONS.

[3] J. F. Fulton, "Selected Readings in the History of Physiology." Springfield, Ill.: Thomas, 1930. Pp. xx + 317.

Professor Fulton presents not only the names of the contributors and their contributions, but also the birth and the death dates of the contributors and the year during which each of the several contributions was first published. Computation of average productivity at each chronological age level (see Fig. 2) was therefore a relatively easy task.[4] It is evident at once that Fig. 2 bears much resemblance to Fig. 1. In each of these curves a definite peak occurs at ages 35 to 39, inclusive, and beyond this age interval both curves exhibit marked declines.

A goiter chronology was found in Professor Robinson's "Syllabus of Medical History."[5] In the latter chronology Robinson endeavored to list fundamental contributions which have to do with either knowledge of, or the treatment of, goiter. Fig. 3 is based upon 52 such contributions that were made by 40 different individuals. In Fig. 3 it was necessary to include the works of both living and deceased contributors in order to obtain sufficient data to yield an age-curve. Despite this fact, the peak of the

[4] Since it is not possible to study the entire life work of individuals who are still living and achieving, Figs. 1 and 2 present data for deceased individuals only. For these the record is complete, and future research will probably change it only slightly, if at all. There is at least one other important reason for omitting the contributions of living individuals. The evaluation of contributions that are made by one's contemporaries is an extra-hazardous undertaking, even when the evaluations are made by experts. With the passing of time a better perspective is likely to be attained, and contributions can then be appraised at more nearly their real worth. Thus, the significance of Gregor Mendel's important paper on genetics was not fully realized until some years after Mendel's death. And the present writer has assembled data which seem to suggest that this was not an isolated instance. Often achievements which are hailed with acclaim by one's contemporaries are regarded as unimportant by a critical posterity. Therefore, unless otherwise stated, the graphs that are presented herein will be based upon the works of deceased individuals only.

[5] V. Robinson, "Syllabus of Medical History." New York: Froben Press, Inc., 1933. Pp. 110. (See p. 83.)

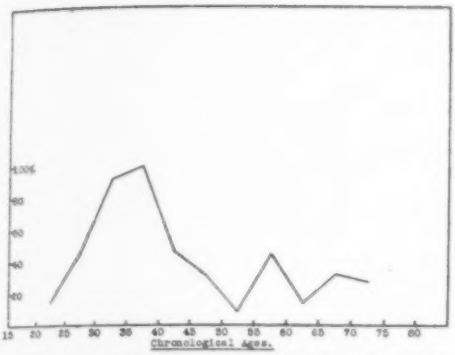


FIG. 3. AVERAGE NUMBER OF CONTRIBUTIONS PER FIVE-YEAR INTERVAL WHICH HAVE TO DO EITHER WITH KNOWLEDGE OF OR THE TREATMENT OF GOITER. THIS GRAPH PRESENTS DATA FOR 40 INDIVIDUALS WHO MADE 52 CONTRIBUTIONS.

curve is again attained at ages 35 to 39, and a sharp descent occurs thereafter.

Fig. 4 presents data for 216 contributions to the science of pathology which were made by 170 different individuals.

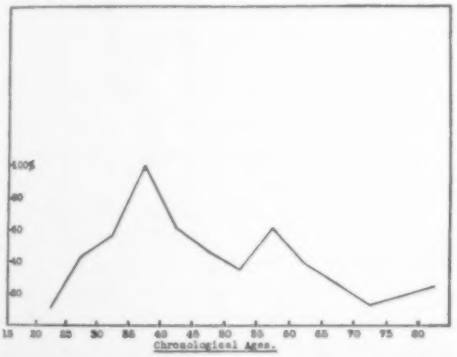


FIG. 4. AVERAGE NUMBER OF CONTRIBUTIONS TO PATHOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 170 INDIVIDUALS WHO MADE 216 CONTRIBUTIONS.

The list of pathological milestones was assembled and published by Professor E. B. Krumbhaar.[6] In Fig. 4 the peak which appears at ages 35 to 39 is even more narrow than are the peaks which are to be found in the three figures that precede Fig. 4.

Fig. 5 presents additional data from the field of pathology. The data for Fig. 5 were obtained from a book by Professor E. R. Long entitled "Selected Readings in the History of Pathology."[7] Although Fig. 5 presents data for only 30 contributions by 27 deceased individuals, it is of interest that this very select group

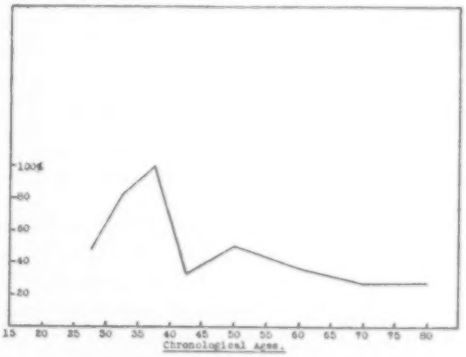


FIG. 5. AVERAGE NUMBER OF CONTRIBUTIONS TO PATHOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 27 INDIVIDUALS WHO MADE 30 CONTRIBUTIONS.

of cases yields a curve in which the peak occurs once again at ages 35 to 39, inclusive. It should perhaps be stated that Fig. 5 was smoothed from ages 40 to 80 inclusive by taking ten years, instead of five, as the unit. This procedure increases the number of cases in each age group. Irregularities are thus eliminated, and the general trend of the age differences is brought out more clearly.

Fig. 6 sets forth 89 advances in the science of anatomy which were made by 70 individuals. The contributions used in the construction of Fig. 6 were listed in F. H. Garrison's "An Introduction to the History of Medicine."[8] This lat-

[6] E. B. Krumbhaar (Editor), "Clio Medica: A Series of Primers on the History of Medicine." XIX, "Pathology," by E. B. Krumbhaar. New York: Paul B. Hoeber, Inc., Medical Book Department of Harper and Brothers, 1937. Pp. xvii + 206.

[7] E. R. Long, Editor: "Selected Readings in Pathology from Hippocrates to Virchow." Springfield, Ill.: Thomas, 1929. Pp. xiv + 301.

[8] F. H. Garrison, "An Introduction to the History of Medicine." Fourth Edition. Philadelphia and London: W. B. Saunders Company, 1929. Pp. 996. (A chronology of medicine and public hygiene is given on pp. 809 *ff.*)

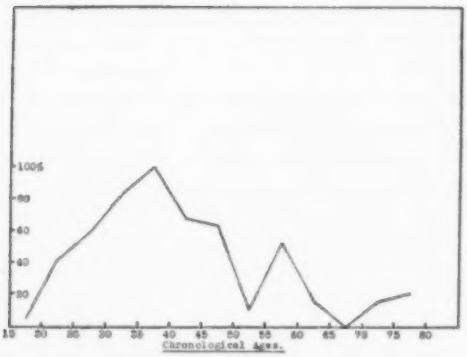


FIG. 6. AVERAGE NUMBER OF ADVANCES THAT WERE MADE IN ANATOMY DURING EACH FIVE-YEAR INTERVAL OF THE SCIENTISTS' LIVES. THIS GRAPH PRESENTS DATA FOR 70 INDIVIDUALS WHO MADE 89 CONTRIBUTIONS.

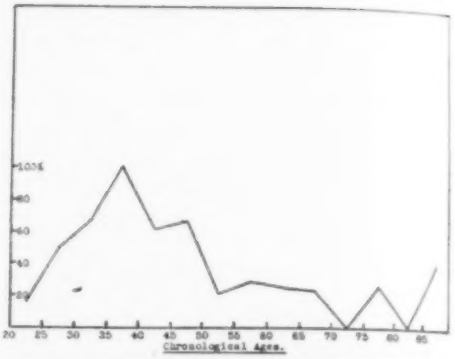


FIG. 7. AVERAGE NUMBER OF MEDICAL DISCOVERIES AND INVENTIONS THAT WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 159 INDIVIDUALS WHO MADE 188 CONTRIBUTIONS.

ter book contains an extensive chronology of medicine, broadly defined, and public hygiene. It will be noted again that Fig. 6 does not differ very greatly in general outline from the figures which have preceded it.[9]

Fig. 7 is based upon 188 medical discoveries and inventions that were made by 159 individuals. The data for this figure were found in B. J. Stern's "Social Factors in Medical Progress."[10] Stern presents a long list of multiple but independent discoveries and inventions in the field of medicine. Stern assembled his list in an attempt to discover whether inventions and discoveries in medicine would not have been made irrespective of the individuals who are now heralded as great innovators. On the basis of his extensive researches Stern asserts boldly that discoveries and inventions depend largely upon antecedent contributions and cumulative social gains. He believes that the alleged genius is largely the product of his environment, the instrument through which an idea or a creation receives expression. Stern therefore insists that practically the same progress would have been made in medicine if any or all of the popularly recognized research heroes had never lived. Whether the validity of Stern's contention be granted or denied, Fig. 7 and the other graphs that are presented herein certainly suggest that chronological age is a very important factor in medical progress.

Fig. 8 is based upon 97 contributions to surgery which were made by 73 individuals.[11] It should perhaps be mentioned at this point that the present article deals not at all with the individual surgeon's technical or diagnostic skill but with recognized advances in the field of surgical knowledge and practice. It is quite possible that a surgeon's own skill may reach its peak later in life, but that his important contributions to his profession are more likely to occur as indicated in Fig. 8.

The data for Fig. 8 were obtained from F. H. Garrison's "An Introduction to the History of Medicine."[12] Although

[9] By identifying in Garrison's chronology those contributions which have been of primary importance to the science of anatomy, Dr. Rush Elliott, of Ohio University, gave the present writer expert assistance in this phase of the present study. Thanks are expressed herewith.

[10] B. J. Stern, "Social Factors in Medical Progress." New York: Columbia University Press, 1927. Pp. 136. (See pp. 11 *ff.*)

[11] Dr. D. H. Biddle, a practicing physician of Athens, Ohio, identified in Garrison's chronology those contributions which have to do primarily with surgery. The present writer is grateful for Dr. Biddle's able cooperation.

[12] F. H. Garrison, *op. cit.*

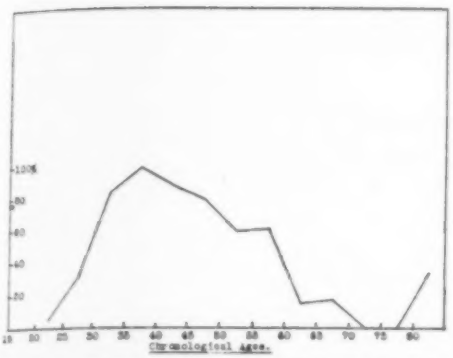

FIG. 8. AVERAGE NUMBER OF ADVANCES IN SURGICAL TECHNIQUE THAT WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 73 INDIVIDUALS WHO MADE 97 CONTRIBUTIONS.

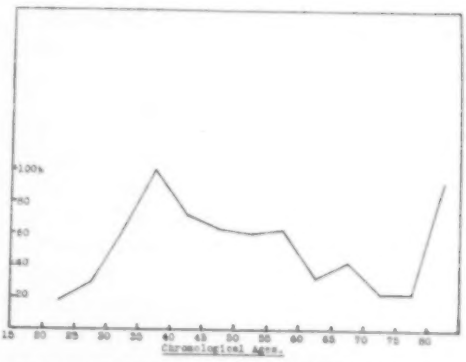

FIG. 9. AVERAGE NUMBER OF CLASSICAL DESCRIPTIONS OF DISEASES WHICH WERE FIRST PUBLISHED DURING EACH FIVE-YEAR INTERVAL OF THE WRITERS' LIVES. THIS GRAPH PRESENTS DATA FOR 102 AUTHORS WHO MADE 147 CONTRIBUTIONS.

the peak of Fig. 8 occurs at ages 35 to 39, it is worthy of mention that the decrement from ages 37 to 57 is less marked than are the decrements which are to be found at corresponding age levels in the curves which have preceded Fig. 8. This more gradual decline in Fig. 8 may possibly be due in part to greater delay in the announcement of surgical advances. Or it may be that, with advance in chronological age, contributions to surgery fall off more slowly than do contributions to the other fields that have been discussed herein.

Fig. 9 sets forth data for 147 classical descriptions of disease which were written by 102 different authors. These descriptions appeared in Dr. Ralph Major's book, "Classical Descriptions of Disease."[13] For the benefit of any who may wish to repeat the present study the following comments regarding the method of tabulating the data from Professor Major's book are included at this point. The dates of the classical descriptions of disease were utilized only when dates of first publication were available. *Post-mortem* publications were ignored whenever it was impossible to ascertain when such publications were written.[14] If Professor Major quoted from a translation or from some edition other than the first edition, the excerpt was counted only when the date of first publication was also available. If excerpts from a given source study appeared under more than one disease-heading in Professor Major's compilation, the source was counted as many times as excerpts therefrom were reproduced in Major's book. For example, age group 80–84 received five credits solely because at 80 G. B. Morgagni published a book entitled "De sedibus et causis morborum," which is quoted at five different places in Major's "Classical Descriptions of Disease." Similarly, age group 30–34 received three credits because at 30 James Hope published a book which is quoted by Dr. Major at three different places. In Fig. 9 the work of one man, G. B. Morgagni, is responsible for the rather marked rise in the curve at ages 80 to 84. Although age group 80 to 84 probably does not deserve sole credit for Morgagni's oft-quoted publication, sole credit was alloted to this age group because it seemed to the pres-

[13] R. H. Major, "Classical Descriptions of Disease." Springfield, Illinois. Thomas, 1932. Pp. xxvii + 630.

[14] The *post-mortem* publications were few in number. The discarding of some of these *post-mortem* contributions has probably not influenced the shape of the age-curves very materially.

ent writer that it would be highly subjective and unfair not to make this allocation of credit.

In general, it will be noted that Figs. 8 and 9 closely resemble each other. Both of these age-curves attain their peaks at ages 35 to 39. Both curves sustain themselves fairly well until age interval 55–59 is attained, and both exhibit a decided decrement beyond age 60. It is possible that Fig. 9 sustains itself so well at the upper-age levels because of the time-lag that may have sometimes occurred between the date of writing a classical description and the date of first publishing it. This latter hypothesis certainly accounts for the final rise of the age-curve in Fig. 9. It is well known that Morgagni spent many years writing his famous book. On the other hand, the relatively slow falling off of the curve in Fig. 9 (at ages 37 to 57) may be due in part to the fact that in many instances the classical description of a disease must be based upon prolonged experience with the disease in question.

Fig. 10 presents information regarding the discovery and introduction of 73 drugs and remedial agents employed in medicine. The 73 contributions were made by 44 persons. The chronology was obtained from Power and Thompson's "Chronologia Medica."[15] Fig. 10 attains its peak at ages 30 to 34, inclusive, thus providing the only instance in the present study in which an age-curve fails to attain its peak at ages 35 to 39.

In his book, "A Hundred Years of Psychology,"[16] J. C. Flugel has published a chronological table of what he describes as "some major events in the history of modern psychology." It was possible to obtain birth and death dates

[15] Sir D'Arcy Power and C. J. S. Thompson, "Chronologia Medica: A Handlist of Persons, Periods and Events in the History of Medicine." New York: Paul B. Hoeber, Inc., 1923. Pp. iv + 278. (See pp. 237 *ff.*)

[16] J. C. Flugel, "A Hundred Years of Psychology." New York: The Macmillan Company, 1933. Pp. 384.

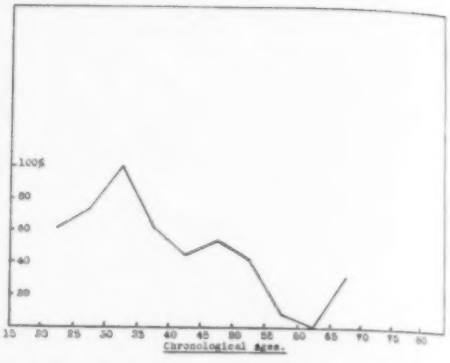


FIG. 10. AVERAGE NUMBER OF DRUGS AND REMEDIAL AGENTS EMPLOYED IN MEDICINE WHICH WERE EITHER DISCOVERED OR INTRODUCED DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 44 INDIVIDUALS WHO MADE 73 CONTRIBUTIONS.

for 50 deceased individuals who made 85 contributions. Fig. 11 reveals the resultant age-curve. The peak again occurs at ages 35 to 39, inclusive.

Fig. 12 presents 801 miscellaneous advances in medicine and in public hygiene which were made by 537 individuals all of whom are now deceased. The data were obtained from F. H. Garrison's book, "An Introduction to the History of Medicine."[17] Garrison's extensive list includes some of the contributions that were listed also in the other chronologies

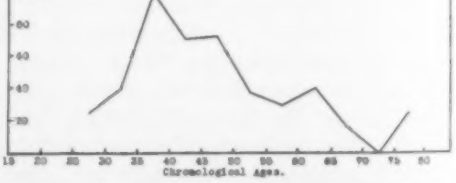


FIG. 11. AVERAGE NUMBER OF CONTRIBUTIONS TO PSYCHOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 50 INDIVIDUALS WHO MADE 85 CONTRIBUTIONS.

[17] F. H. Garrison, *op. cit.*

that have been employed in the present study. Therefore, some of the advances utilized in the construction of Fig. 12 were used previously in the construction of the other graphs that have been presented. Many of the 801 contributions, however, have not been previously employed.

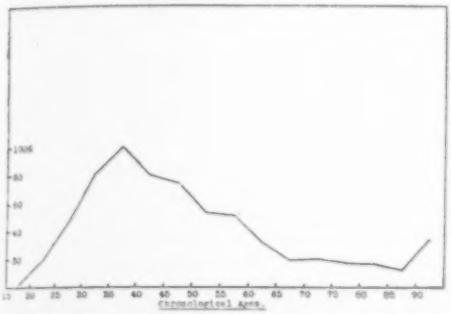

FIG. 12. AVERAGE NUMBER OF ADVANCES IN MEDICINE AND PUBLIC HYGIENE WHICH WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 537 INDIVIDUALS WHO MADE 801 CONTRIBUTIONS.

It will be noted that Fig. 12 has a smoother appearance than have most of the age-curves which precede it. This finding is due in part perhaps to the fact that Fig. 12 is based upon a relatively large number of cases. Like ten of the eleven figures which preceded it, Fig. 12 shows a peak at ages 35 to 39, inclusive. On the whole, the assembled data strongly suggest that, in proportion to their numbers, men have made contributions to medicine most frequently while they were still in their thirties. In eleven of the twelve age-curves that are shown herein the peak of productivity occurs at ages 35 to 39, inclusive. In the one remaining curve the peak occurs at ages 30 to 34, inclusive.

## Further Remarks

In the preparation of this article the contributions of great men have been studied. Collectively, these men have probably done more for humanity than have all the warriors and statesmen and politicians who ever lived. It has been a privilege to contemplate the achievements of these creators of modern medicine and surgery. It is a pleasure to know that the age-long search for new means of controlling disease and human suffering is to-day receiving more positive aid and encouragement than perhaps ever before in the history of the race.

In the field of medicine, as in other fields, man's progress has frequently been opposed by ignorance, bigotry, stupidity, ridicule, intolerance and the pressure of poverty. Religious beliefs too have often been a major obstacle to further immediate advance. Some potential contributors to medicine have perhaps been crushed by one or more of these hostile forces; others possibly have only been stimulated by them to fight more vigorously for their convictions. William Harvey reported on the circulation of the blood when he was past fifty, but there is evidence that he discovered this phenomenon some years earlier and delayed publication as a matter of precaution. Histories of medicine reveal that such delay in making announcements of new medical discoveries has been frequent. There often were very good reasons for withholding such announcements. For example, when Harvey finally published his discovery that the blood circulates in the human body his professional colleagues only jeered him and there was an immediate falling off in Harvey's medical practice. Many of his patients refused to be treated any longer by one who gave such clear evidence of what seemed to be obvious insanity.[18]

Because of the time-lag that must often have occurred between the date of a discovery and the date of its publication, it seems evident that, at the upper-age levels, the accompanying age-curves are too high rather than too low. As for the general shape of the curves, and particularly the age intervals at which the peaks are found, it is the belief of the present writer that these are as accurate a picture

[18] *Ibid.*, p. 249.

of the relative productivity of the various age groups as can be obtained with the data that are at present available.

In the first paragraph of this article a warning was uttered about the erroneous impression that is likely to ensue if one depends too much upon one's impressionistic judgment. History provides some conspicuous instances in which impressionistic judgments have been misleading. That oft-misquoted remark which was made by Sir William Osler in 1905 will doubtless be recalled by many who read this article. Before quoting Osler's statement it will be desirable to review briefly the circumstances under which the statement was made. Dr. Osler had served as professor of clinical medicine at The Johns Hopkins University School of Medicine from 1889 to 1905. At the latter date he was appointed regius professor of medicine at Oxford University. At a banquet which was held in his honor Dr. Osler gave a farewell address. Because so many persons had expressed their dismay over his departure, Dr. Osler, with becoming modesty and in a spirit of levity, assured those persons that his departure was inconsequential. In making this remark Osler, who at that time was 56 years of age, meant to imply that his most important work had already been done. In the farewell address which followed Osler stated in somewhat greater detail his thesis that the effective, vitalizing, moving work of the world is likely to be done by men who are between the ages of 25 and 40. The following quotation is taken from a book by Lambert and Goodwin.[19]

> One of Osler's addresses brought him unmerited notoriety. The occasion was his farewell address at Johns Hopkins. In it he said: "I have two fixed ideas well known to my friends, harmless obsessions with which I sometimes bore them, but which have a direct bearing on this important problem. The first is the comparative uselessness of men over forty years of age. This may seem shocking and yet, read aright, the world's history bears out the statement. Take the sum of human achievement in action, in science, in art, in literature—subtract the work of the men above forty, and while we should miss great treasures, even priceless treasures, we would practically be where we are today. . . . My second fixed idea is the uselessness of men above sixty years of age, and the incalculable benefit it would be in commercial, political, and in professional life if, as a matter of course, men stopped work at this age." He then went on in a semi-humorous vein to refer to a novel of Anthony Trollope's describing a college which men entered at sixty for a year's period of contemplation before their peaceful departure by chloroform. "Whether Anthony Trollope's suggestion of a college and chloroform should be carried out or not," he said, "I have become a little dubious, as my own time is getting so short." Unfortunately, the press during a time of lull in actual news scented a sensation in his remarks and soon head-lines appeared saying that "Dr. Osler Recommends Chloroform for Men of Sixty." This precipitated a wide-spread discussion often heated and even bitter by those of whom many had never read what he had actually said. A new phrase —to oslerize—was added to the language indicating the extinction of men of sixty. Osler recognized that he was the victim of misguided reportorial zeal, that explanations under the circumstances were useless, and let the storm blow itself out.

[19] S. W. Lambert and B. M. Goodwin, "Medical Leaders from Hippocrates to Osler," p. 326 *f*. Indianapolis: The Bobbs-Merrill Company, 1929. Pp. 331.

The comments and the criticisms which were elicited by the distorted form in which Osler's remarks received world-wide attention would make a long bibliography. Curiously enough, fate seems to have decreed that Osler will be remembered longest for a remark which he did *not* make.

In the foregoing quotation Dr. Osler speaks of "the *comparative uselessness* of men over forty years of age" and of "the *uselessness* of men above sixty years of age." (The italics are mine.) Although the age-curves that accompany the present article attain their peaks in the thirties, analysis of the data fails to support the thesis that men cease to make useful contributions at *any* specific chronological age level. On the contrary, these data suggest that it is possible for individuals to think creatively and to make invaluable contributions at prac-

TABLE I

SUMMARY OF FINDINGS WITH REFERENCE TO THE CREATIVE YEARS IN MEDICINE

| Data used in | Source of data | No. of contributions | No. of contributors | Ave. contributions per contributor | Median age | Mean age | Standard deviation | Years of maximum productivity |
|---|---|---|---|---|---|---|---|---|
| Fig. 1 | C. B. Morrey | 50 | 41 | 1.22 | 38.80 | 41.20 | 12.05 | 35–39 |
| Fig. 2 | J. F. Fulton | 59 | 54 | 1.09 | 41.33 | 43.50 | 12.30 | 35–39 |
| Fig. 3 | V. S. Robinson | 52 | 40* | 1.30 | 37.33 | 40.10 | 11.60 | 35–39 |
| Fig. 4 | E. B. Krumbhaar | 216 | 170 | 1.27 | 42.50 | 44.76 | 13.10 | 35–39 |
| Fig. 5 | E. R. Long | 30 | 27 | 1.11 | 43.00 | 45.67 | 14.00 | 35–39 |
| Fig. 6 | F. H. Garrison | 89 | 70 | 1.27 | 36.38 | 38.85 | 11.70 | 35–39 |
| Fig. 7 | B. J. Stern | 188 | 159 | 1.18 | 39.50 | 41.82 | 12.15 | 35–39 |
| Fig. 8 | F. H. Garrison | 97 | 73 | 1.33 | 42.30 | 43.89 | 10.45 | 35–39 |
| Fig. 9 | R. H. Major | 147 | 102 | 1.44 | 43.79 | 46.61 | 13.80 | 35–39 |
| Fig. 10 | Power and Thompson | 73 | 44 | 1.65 | 34.70 | 37.02 | 11.25 | 30–34 |
| Fig. 11 | J. C. Flugel | 85 | 50 | 1.70 | 42.75 | 44.50 | 11.30 | 35–39 |
| Fig. 12 | F. H. Garrison | 801 | 537 | 1.49 | 41.18 | 43.17 | 12.45 | 35–39 |

* Data for some living contributors are included in this curve.

tically every chronological age level beyond early youth. De Réaumur, for example, was 69 years old when he carried out his memorable observations upon the digestive juices of his pet kite. And, of the 87 works that are included in his "Selected Readings in the History of Physiology,"[20] Fulton reports that 42 of them were written when their authors were past forty.

To cite such facts without surveying all the pertinent data may be misleading. What is to be found when such a survey is made? In Table I the sixth column sets forth the median chronological ages of the contributors whose works have been employed in constructing the 12 graphs that accompany this article. It will be noted that five of the twelve medians fall between ages 30 and 40, and that seven of them fall beyond age 40. The fact that the mid-point of the twelve medians lies at age 41.25 implies that, although the rate of output was greatest prior to age forty, only about half of the sum total of these brilliant medical contributions were made (or first published) prior to age forty. This situation will be readily understood if it is noted that the age-curves fall much more slowly than they rise. It seems obvious that, in medicine and its allied fields, creative thinking does not cease at age forty or even at age sixty.

[20] J. F. Fulton, *op. cit.*

Let us examine Table II, which sets forth the average number of contributions per five-year interval. Forty-nine of the averages that are shown in Table II are based upon the works of individuals who were less than forty years of age, but 87 of these averages are based upon the contributions of individuals who were past forty years of age at the time of announcing their discoveries. A total of 1,888 medical contributions was utilized in the preparation of Table II.[21] Tabulation of the ages of those who were responsible for these 1,888 medical contributions reveals that 906 of the contributions (48 per cent.) were announced by individuals when they were less than forty years of age, whereas 982 of them (52 per cent.) were either made or first published by individuals who were past forty years of age. These figures again emphasize the fact that a distinction needs to be made between rate of contributing and the sum total of output of very superior contributions.

Table III, which is based upon data taken from Garrison,[22] brings out the individual differences in the chronological ages of the contributors even more

[21] This total was obtained by counting each contribution as many times as it was listed in the various chronologies. Some of the contributions were therefore counted more than once. The difference that would have resulted at any one age level in Table II had such duplication been avoided is probably slight.

[22] F. H. Garrison, *op. cit.*

TABLE II

AVERAGE NUMBER OF CONTRIBUTIONS PER FIVE-YEAR INTERVAL*

| | Chronological age interval | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15–19 | 20–24 | 25–29 | 30–34 | 35–39 | 40–44 | 45–49 | 50–54 | 55–59 | 60–64 | 65–69 | 70–74 | 75–79 | 80–84 | 85–89 | |
| Fig. 1 | .005 | .101 | .030 | .040 | *.050* | .025 | .035 | .011 | .022 | .023 | .006 | | | | | |
| Fig. 2 | | .007 | .019 | .034 | *.050* | .031 | .016 | .029 | .028 | .000 | .026 | .001 | | | | |
| Fig. 3† | | .010 | .030 | .060 | *.065* | .030 | .021 | .006 | .029 | .009 | .021 | .002 | | | | |
| Fig. 4 | | .006 | .024 | .031 | *.055* | .033 | .026 | .019 | .034 | .021 | .014 | .007 | .011 | .014 | | |
| Fig. 5 | | | .022 | .038 | *.046* | .015 | .032 | .024 | .008 | .026 | .000 | .029 | .018 | | | |
| Fig. 6 | .003 | .022 | .031 | .044 | *.053* | .036 | .034 | .005 | .028 | .009 | .000 | .009 | .011 | | | |
| Fig. 7 | | .009 | .027 | .036 | *.054* | .033 | .036 | .011 | .015 | .014 | .012 | .000 | .014 | .000 | .022 | |
| Fig. 8 | | .003 | .016 | .044 | *.052* | .041 | .037 | .032 | .032 | .008 | .010 | .000 | .000 | .017 | .056 | |
| Fig. 9 | | .009 | .016 | .033 | *.053* | .038 | .034 | .032 | .033 | .017 | .023 | .012 | .041 | | | |
| Fig. 10 | | .046 | .054 | *.074* | .047 | .034 | .040 | .031 | .006 | .000 | .024 | | | | | |
| Fig. 11 | | | .028 | .032 | *.080* | .056 | .058 | .030 | .024 | .032 | .013 | .000 | .020 | | | |
| Fig. 12 | .001 | .011 | .026 | .045 | *.056* | .045 | .042 | .030 | .029 | .018 | .011 | .011 | .009 | .009 | .007 | .019 |

* The peak of each statistical distribution is italicized.
† This figure includes data for some living contributors.

clearly. Thus, Table III reveals that 18 per cent. of the 801 contributions listed by Garrison were either made or first announced by persons of ages 35 to 39, inclusive, that 4 per cent. of them were first published by persons of ages 60 to 64, inclusive, that 10 per cent. of them were first published subsequent to age 60, and so forth.

Letters that have been received from persons who read the first of this series of articles[23] afford convincing evidence that, in spite of all that may be said by way of explanation, the accompanying age-curves will be misleading to some readers. For example, one individual who was permitted to see these age-curves prior to their publication remarked that in his opinion these curves rise and fall "much too rapidly." Further conversation revealed that this individual was laboring under the misapprehnsion that these age-curves are intended to picture the growth and the decline of *individual ability* to do creative thinking.

The present study does not pretend to measure any hypothetical "ability" to do creative work. This study deals only with behavior—the specific kinds of behavior that have been cited. If behavior were due solely to "ability," the interpretation of the data would be very much simplified. In order to picture *individual* growth and decline in creative *ability* it would be necessary to measure creative ability in the same individuals at successive chronological age levels and over a long period of time. Although the present writer has not assembled such data, nor does he know how this could be done, it seems probable that individual age-curves portraying creative ability, if such curves could be obtained, would reveal a much more gradual rise and a much more gradual decline than do the age-curves which are included in this article.

It may well be that future generations will not take seriously many of the pres-

[23] H. C. Lehman, *op. cit.*

TABLE III

(A) NUMBER OF MISCELLANEOUS ADVANCES IN MEDICINE AND IN PUBLIC HYGIENE WHICH WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES BY 537 INDIVIDUALS ALL OF WHOM ARE NOW DECEASED, (B) PER CENT. OF THE TOTAL OF 801 CONTRIBUTIONS WHICH WERE MADE DURING EACH FIVE-YEAR INTERVAL, AND (C) PER CENT. THAT WERE MADE SUBSEQUENT TO THE BEGINNING OF EACH FIVE-YEAR INTERVAL. DATA FROM F. H. GARRISON

| Age group | No. of cont. | Per cent. of total | Per cent. made subsequent to various ages | |
|---|---|---|---|---|
| | | *Per cent.* | *Age* | *Per cent.* |
| 15–19 | 3 | 0.5 | 15 | 100 |
| 20–24 | 29 | 4 | 20 | 99.5 |
| 25–29 | 69 | 9 | 25 | 96 |
| 30–34 | 121 | 15 | 30 | 87 |
| 35–39 | 148 | 18 | 35 | 72 |
| 40–44 | 116 | 14 | 40 | 54 |
| 45–49 | 104 | 13 | 45 | 40 |
| 50–54 | 70 | 9 | 50 | 26.5 |
| 55–59 | 63 | 8 | 55 | 18 |
| 60–64 | 35 | 4 | 60 | 10 |
| 65–69 | 17 | 2 | 65 | 5.5 |
| 70–74 | 13 | 2 | 70 | 3 |
| 75–79 | 7 | 1 | 75 | 2 |
| 80–84 | 4 | 0.5 | 80 | 1 |
| 85–89 | 1 | ... | 85 | .... |
| 90–94 | 1 | ... | 90 | .... |
| Total | 801 | 100 | .. | .... |

ent-day attempts to measure the "intelligence" of adults of widely varying ages. Can intelligence be disentangled from such other factors as: (1) motivation to learn; (2) pressure to utilize fully what has been learned; (3) the plasticity of the nervous system; (4) relatively fixed, unalterable attitudes; (5) level of functioning; (6) physical stamina; (7) environmental opportunity; and the like? Is it possible to motivate the older individual to the same extent that the youth can be motivated, if the oldster has attained many of his life goals, and if the youth has reached few of his goals? Is it valid to assume that in our rapidly changing civilization the older adult has had the same intellectual diet (opportunity to learn) as has the younger adult? The present writer knows of no evidence which permits an affirmative answer to the foregoing queries. Nor does the present writer believe that it has been possible for psychologists to apply the law of the single variable when making their studies of "adult intelligence."

The fact that the age-curves apply only to group behavior is not the sole reason why they fall so rapidly. It seems that a second factor which causes the rapid early decrement is the very superior quality of the performance. In previous articles[24] data were published which suggest that the shape of an age-curve varies both with the type of function that is measured and also with the excellence of the performance. Thus, very superior books are likely to be written during a somewhat narrower age range than are books of lesser merit. The foregoing situation seems to hold also for a number of other behaviors—for musical composition, for athletic performance and for several kinds of scientific endeavor.[25] For the above types of behavior, the more noteworthy the performance, the more rapidly does the resultant age-curve descend after attaining its peak. It therefore seems safe to conclude that quality of performance is one reason why the accompanying age-curves fall so rapidly.

Just why brilliant attainment in these diverse fields of endeavor should cease at earlier age levels than does more mediocre performance the present writer does not know. It is easy to speculate with reference to the cause-and-effect relationship; it is much more difficult to validate one's speculations. The rapid descent of the age-curves that are presented herein might conceivably be due either to: (1) the inevitable organic changes that take place within the individual (the reverse of maturation), (2) environmental factors or (3) a combination of organic and environmental factors. It is also quite possible that no general rule is applicable, *i.e.*, some individuals may exhibit an early decrement in the quality of their performance because of organic changes; others may exhibit a similar decrement because of environmental factors or because of a particular combination of organic and environmental factors. If the early decrement in brilliant performance is due to biological factors, it may not be possible to do anything to preclude or even to reduce in amount this early decline. If, however, environmental factors are responsible for the early descent of the age-curves, then it is quite conceivable that the causative factors may some day be subject to a measure of control.

In a study such as this one it obviously would be very difficult and time-consuming to identify the causative (concomitant) factors; in such complex behavior the relationship between cause and effect is likely to be obscure. However, the problem is not hopelessly difficult. Because the promotion of creative thinking is so tremendously important to human welfare, the causative factors should be ascertained if it is at all possible to do so. Certainly, this problem is one that merits serious study.

[24] *Ibid.*

[25] Data which support the above statement with reference to scientific endeavor are not yet ready for publication.

# HEREDITY AND MENTAL TRAITS

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IT seems to be easier for us to accept as true something we can see, like a meteorite or a club foot, than something we can infer only from indirect data, like the span of years elapsing since the Stone Age, or differences in the educability of human beings. Yet we should not forget in this connection the story in which our professor of logic used to delight, about the fisherman who came home with a large black bass and a tall fish story, "with the fish to prove it!"

When it comes to the problem to be discussed in the present paper, there is an important obstacle to clear thinking which often hampers even the sophisticates who can accept without resistance such unseen truths as relativity mechanics. Not only some observers and interpreters of science, but some research workers themselves, have shown a liability to emotional blocking on questions which concern the mental endowment and plasticity of man. Supposedly this is because the results of studies in this field impinge upon one's life philosophy and attitudes toward his fellows, and thus one comes to care very deeply about the outcomes.

The difficulties and controversies which ensue are understandable, but they mean that the person who would consider the many sources of evidence objectively must use more than ordinary caution. If he is willing to consider only the evidence—apart from the conflicting claims that are frequently made—he will find a surprising amount of consistency in the facts now at his disposal.

We may start with a discussion of intelligence, since this is the aspect of mental life on which the most definitive research has been conducted up to now. Like so many questions having lively interest to-day, the inheritance of intelligence was also considered by the Greeks, and in Plato's "Republic" one may find modern ideas couched in classical allegorical form regarding the biological basis of talent:

> Although your children will generally resemble their parents, yet sometimes a golden parent will produce a silver child, and a silver parent a golden child, and so on, each producing any. . . . There is an oracle that declares that the city shall then perish if it is guarded by iron or copper.

## FAMILY RESEMBLANCE STUDIES

It was not until Francis Galton, with his "Hereditary Genius" published in 1869, introduced a method for appraising kin resemblance through the number of highly superior persons who clustered in family lines, that "nature-nurture" investigations began to come from men of science, although the great religions and political states had been built around the idea of men endowed to lead. Galton's study, which showed that men of genius were many times more likely to have genuises among their close relatives than were men at random, stimulated a legion of followers who compiled studies on the defective end (*e.g.*, the Jukes and Kallikaks) as well as the upper end of ability. As quantitative trait-rating devices, and more recently, standardized intelligence tests have come into use, correlation coefficients have replaced mere counts of the incidence of high and low ability in relatives of specified degree. The close comparability of correlations between parents and offspring, or between brothers and sisters, on mental traits and on physical traits such as stature, caused the great biometrician Karl Pear-

son to conclude that "mental characters are inherited in precisely the same way as the physical." It has been often enough pointed out since Pearson's heyday, however, that environment might simulate heredity in producing family resemblance and that additional data are required to disentangle nature and nurture when the biological quality of families is correlated with the environment selected by and even created by the families.

### Studies of Twins

The study of twins appeared to many investigators to be a way out of the impasse encountered in ordinary family resemblance studies. As is now widely known by laymen and biologists alike, there are two kinds of twins, one kind derived from a single fertilized ovum, and thus "identical" in heredity, and the other kind derived from two fertilized ova, and thus like ordinary brothers and sisters in degree of hereditary "overlapping." If one-egg twins resemble one another distinctly more than two-egg twins do on physical and mental traits, this is taken as presumptive evidence that heredity is at work. Many studies of twins are now available, and these have dealt not only with intelligence, but with school attainment, physique, susceptibility to disease, interests, attitudes and personality adjustments. We do not wish to encroach upon the field discussed by Rife in his paper on twins in this series of articles, but will take space to comment on a few points relevant to our immediate problem.

In the first place one-egg twins really have a somewhat more similar environment than do two-egg twins, even if reared in their own homes by their own parents. It is shown clearly, for example, in a California study by Wilson, that "identical" twins are treated more similarly by their relatives and friends, and are more similar in habits of eating, sleeping and recreation. While such factors would presumably not affect traits like eye color and finger-print patterns and other physical traits which, because of their stability in the individual, are actually used as criteria for judging whether twins are of one-egg or two-egg origin, they might account at least in part for the greater similarity of one-egg twins in mental development.

There is another approach to the study of twins, on the other hand, which partakes more of the nature of experiment, or at least utilizes the results of social experiments already made. This is the study of one-egg twins who have been separated in infancy and brought up in different environments. To the extent that twin-pair resemblance shows up even when environment has had no chance to contribute to it, we can say that heredity is demonstrated. But when the separated twin-pairs show differences, and particularly when these correspond to identifiable differences in childhood environment, we have a way of appraising non-hereditary contributions. Newman and his colleagues at the University of Chicago have studied twenty separated pairs, and other investigators, including the writer, have studied several additional pairs. The intra-pair mental development of the twins tended to be very similar when differences in their educational opportunities were not too large. This carries the implication that mental differences found among people living in similar communities and having fairly similar schooling are largely *native* differences. There were several pairs of twins, however, whose schooling was extremely dissimilar, and these twins scored far apart on intelligence tests. For example, one young woman had had a college education and had taught school, while her twin had had only two years of grade school education. The difference in their IQ's was 24 points in favor of the college twin, and the differences in their social abilities were fully as striking.

### Studies of Foster Children

Probably studies of identical twins reared apart are the most effective of any that have or could be undertaken for unravelling the nature-nurture problem. Such pairs have been located so rarely, however, that other kinds of crucial data have necessarily been sought. Children placed in foster homes during infancy, even when they are not twins, have provided some important evidence, since they have the virtue for research purposes of living in environments that are usually quite different from what their own parents could have provided. We may briefly summarize the chief findings of the main studies of this type:

Theis's 1924 study was the first large follow-up ever made. She found that children placed in foster homes when under five turned out to be more capable adults (on the average) than those placed when over five. It is possible, however, that children who become dependent at later ages come from less promising family stock than those who become dependent in infancy. (Later foster child studies would support this possibility.)

The most interesting finding was a relationship close to zero between home ratings on cultural and material status with "capability" of the foster children as adults, but accompanied by a distinct positive relationship between "kind of care" received and "capability," from which the inference followed: "Undoubtedly the child's adjustment to his foster family governs to a significant degree his adjustment to society, and his adjustment to his foster family has less to do with their standards of comfort and their place in the community than with their human qualities and their understanding." Still further comparisons showed a positive relationship between "capability" and *true* family background. As Folks points out in the introduction, however: "We can not disentangle the factor of inheritance from that of early life with the children's parents and the environment provided by them."

Burks (1928) compared the mental resemblance between 200 foster children (placed when under a year of age) and their foster parents with that between 100 "own" children and "own" parents of similar socio-economic and intellectual range. The resemblance in the foster families was very slight as compared with that in the "own" families. "Own" children averaged 8 points higher than foster children. From results on a composite rating of home environment, it was concluded that measurable factors of home environment (under fairly homogeneous community and educational conditions) contributed about 17 per cent. to the variance of children's IQ's. Wright (1931) later reworked the data and concluded that the total role of environmental (non-genetic) influences in this group could be placed with fair probability between 10 and 50 per cent.

Freeman, Holzinger and Mitchell (1928) tested foster children and foster parents, foster siblings (*i.e.*, foster brothers and sisters), and true siblings growing up in separate homes. The correlation of foster parents and children was somewhat higher than that found in the previous study, but "selective placement" was not ruled out by the method used for acquiring cases. Foster sibling groups showed IQ correlations of .34 to .40, which may have been due partly to environment and partly to selective placement. True siblings of white race in separate homes correlated .44 after allowance was made for poor test standardization in certain age ranges. This value, in turn, may have been due partly to heredity and partly to selective placement. Children who were old enough to test before placement gained about 7 points on the average after several years of residence in good foster homes.

Leahy (1935) undertook an investigation for the purpose of resolving the disparities between the two preceding studies, and went to unusual pains to obtain a group of foster subjects placed when very young and unselectively. Her correlation figures check closely with those of Burks.

The results of the Leahy and Burks studies were recently re-examined by Burks (1938) in cooperation with Sewall Wright in order to evaluate the contributions of nature and nurture to average group differences in intelligence. This problem is essentially different (though not wholly unrelated) from that of ascertaining the factors contributing to the distribution of individual scores. Although hierarchial differences are ordinarily small as compared to individual differences *within* "census groups" of occupations or other variables, they are by no means negligible (*e.g.*, IQ's often average as high as 115 or 120 for children of professional parents, and appreciably below 100 for children of unskilled laborers).

Taking the parental occupational hierarchy found in the IQ's of foster and control children of the two studies, it was possible to estimate through Wright's path coefficient method that the differences in occupational group averages of the "own" children could be attributed about $\frac{1}{4}$ to $\frac{1}{2}$ to environment, $\frac{3}{8}$ to $\frac{3}{4}$ to heredity.

Skodak (1939) recently published a study on foster children of preschool age (continuing studies undertaken by Skeels at the University of Iowa). Widely heralded conclusions arose from average IQ's of 116 reported for 2-year-old foster children in this group, the experimenters remaining seemingly unaware of the faulty standardization and inflated norms of the Kuhlmann-Binet test in the early years. When the data are reworked it is found that year by year (age $1\frac{1}{2}$ to 6) the IQ's average about 6 or 7 points above corrected norms—results which were also found in the previous foster child studies (for subjects of comparable selection), and which can probably be attributed to good environment, although they are not nearly so sensational as the Iowa claims. As in the Freeman study, a group of children old enough to test before placement gained (5.7 after one year and 9.8 points after two years) following foster home residence.

Much was made in the study of the failure of "true family background" to give a prediction of the IQ's of the youngest (two-year-old) children of the group, but no emphasis was given to the fact that foster home status likewise failed to correlate with the IQ's of the children in the youngest ranges. Despite the fact that IQ correlations increased with age both for true parent and foster parent variables, and by the age of six gave a higher value with education of true parents (with whom the children had never lived) than with education of foster parents, the author offered in her main conclusions these *non-sequiturs:* "Placing the child in a good foster home at the youngest possible age makes for development equal to own children in similar homes"; "the relationship between true-family background and the child's mental development is approximately zero"; "the use of true-family histories as a basis for the placement of the child has little or no justification."

Lawrence's 1931 study of children separated from their homes in infancy and tested after some years of institutional life showed an IQ hierarchy following the occupational status of the true father, although the differences were less marked (about 6 points from highest to lowest occupational groups) than with children reared in their own homes. It is not known to what extent the institutional environment, and to what extent atypical representation from the various

occupational groups of children becoming institutional wards, accounts for the reduction in hierarchical differences. To the extent that differences did remain, heredity was probably responsible.

### Studies of Changes Under Particular Environmental Influences

In addition to the studies which have attempted to separate the contributions of nature and nurture to individual differences, or to differences between groups of children (or adults), there are a number of studies which approach the problem of environment through the observation of *changes* in mental status under specified conditions.

Improvement in IQ (averaging 5 to 10 points) of foster children placed in good foster homes from poor "own" homes was mentioned in several of the studies just summarized. There are other studies which consider the problem by making *age* comparisons of children growing up under deprived environmental conditions. One of the first of these was Gordon's investigation (1923) of English canal boat children. With almost a total lack of schooling, and with little intellectual stimulation in their houseboat homes, the IQ's of these children showed steady decrease from year to year, so that the average of the twelve-year-olds was nearly 30 points less than that of the six-year-olds. In this study the meagerness of the environment was extreme; other studies have not found as large a disparity between the older and younger subjects of deprived groups, although it has not been unusual to find decreases of 10 to 20 IQ points in a comparable age range among children living in isolated mountain regions, in mill towns of sub-standard cultural opportunities, etc.

Several studies have been undertaken, particularly at the University of Iowa, for appraising the contribution of nursery school training, and of "progressive school" training, to mental development. It is clear that such studies, unless carried out under rigorous experimental control, offer loopholes for great ambiguity, due to the fact that parents who send their children to nursery schools and to private or university-sponsored progressive schools are not a random selection of parents, nor are their children a random cross section of children. Although large claims have been made for the effect of certain types of schooling upon the IQ, it is usually far from certain that the effects are really those of education. Even when groups of young children are "matched" for IQ at the beginning of their nursery school careers, and are later (at college age) found to have disparities that correspond to differences in their educational experiences, the evidence is not clear-cut because IQ's obtained during the preschool years do not give a dependable prediction of developmental potentiality. Thus the later disparities may be due wholly or in part to "selection" of children with higher or lower potentialities. In general it can be said that the better the experimental control in such investigations, the less is the apparent effect of educational variables.

### Racial Differences

Though differences in the *average* mental test scores of persons of various natio-racial origins are quite regularly found, these are accompanied by so many differences in environmental training and opportunities, and the *overlapping* among the groups is so large, that anthropologists have quite rightly pointed out the hazards of drawing conclusions regarding innate racial differences merely from mental test surveys. In the United States certain so-called "census groups," in particular the Negroes and some South European groups, especially Italians, have showed a handicapping in mental tests as compared with

North European and Jewish groups. We have very little data, however, by which to interpret the sources of the differences, although there are certain facts that are not incompatible with an explanation on partly biological grounds. We have, for example, a series of studies on the distribution of a variety of simple genetic traits, not associated with racial differentiae *per se*, in natio-ethnic groups occupying different geographical regions. In all such studies (which have dealt with the blood groups, with "taste-blindness" for certain chemicals, with the presence or absence of hair over the middle segment of the fingers, etc.) it has been demonstrated that the incidence rate of traits whose effects are little modified by environment does tend to vary in groups characterized by different racial ancestry. If this is so with genes for physique, then why not with genes for intellect as well?

Such an argument is of course suggestive and not at all conclusive. Of crucial evidence for innate racial differences in intellect we have virtually none. On the contrary, we have a series of studies by Klineberg and his associates who took as subjects ten-year-old Negro children who had lived for varying periods of time in New York City. Recent migrants from the South averaged lowest, and those who were born in New York or had lived there over five years, averaged highest. For example, in one of the studies the former averaged 81 IQ and the latter, 87 IQ. The difference is referred to the better school advantages available to Negroes in the North, although even so, an unexplained disparity remains between the Negroes and Whites. Whether that is due mainly to nature or to nurture is a speculative question that can not be answered by data now available.

### Non-Intellectual Mental Traits

We have seen considerable evidence that heredity lays down the limits within which intelligence can develop, but that environmental effects of 5 to 10 IQ points occur under certain conditions, and that effects of 20 points or even more occur under extreme conditions.

Can any similar conclusions be drawn for traits or behavior representing the emotional and volitional aspects of mental life? For interests, for traits of leadership, for anti-social tendencies, for self-control or for proneness to mental breakdown?

Research in these domains seems to have advanced little beyond the place that research on intelligence had reached two decades ago. There are studies of marked personality deviations in kinships, including twins. Such studies show in leadership, nomadism, criminality, psychosis, epilepsy, etc., much the same tendency for clustering in family lines that is found for feeble-mindedness and high ability, and also higher resemblance among one-egg twins than among two-egg twins. But the clinching evidence from foster children and from twins reared apart is available so far in only meager quantity. This is partly because *extreme* deviations like criminality and psychosis happen too rarely to have occurred with much freqnency in the groups of foster children and separated twins that have been studied up to now. Though it might seem that less extreme characteristics of personality could be studied with profit, we have few measuring instruments at all comparable in validity with intelligence tests in the field of personality, and consequently most of the personality data on foster children and twins reared apart—aside from diagnoses of actual pathology, and some scores on rather unreliable tests, are stated in unsystematized terms that are difficult to evaluate. Nevertheless, some of the data, especially on the separated twins, have extreme interest.

Rosanoff has reported on a pair of twin girls separated in infancy and unaware of one another's existence who both developed epilepsy and promiscuous sex behavior. They were recognized as identical twins in the state institution to which they were both committed through their nearly identical appearance and behavior.

Burks has studied a pair of twin girls separated nearly at birth who developed very similar behavior problems in childhood, *e.g.*, nail-biting, enuresis, hyperirritability. One twin, however, received a more indulgent upbringing, and was "favored child" above a foster sibling reared in the same home, while the other twin was reared under more exacting and less affectionate home conditions. The more favored twin has been happier and more successful in school, social and occupational adjustments.

The Newman, Freeman and Holzinger studies of twins reared apart, as well as containing considerable data on parallel traits of personality, include some striking observations on personality differences that were related to differences in childhood experiences. There was, for example, the boys of a pair reared in the city and country respectively, the city twin impressing the research staff as being "more dignified, more reserved, more self-contained, more unafraid, more experienced, and less friendly." In another pair of boys, the patterns of their foster families, in one case respect and in the other case disrespect for the law, were taken over in a way that markedly affected the trends of their lives.

It is clear that one of the most urgent needs in the field is for more studies on separated twins and foster children making use of the best methods now available for appraising hereditary background and environment as well as personality development. Such studies promise high rewards not only for science, but for man himself in his efforts to come to terms with the requirements of his social *milieu*.

# BOOKS ON SCIENCE FOR LAYMEN

## MYSTERIES OF THE MIND[1]

One of the very provocative writers on psychoanalysis is the distinguished Swiss physician, Carl G. Jung, the author of the present volume. A charming person, a profound scholar of wide erudition and a true philosopher, he has exerted a great influence on the thinking of many persons.

Starting as a fellow worker with Freud, he broke with him and set up what may be referred to as a schismatic school of thought, characterized especially by its stress upon what Jung terms the "collective unconscious." To Jung there are depths of the unconscious which lie deeper than early and "forgotten" experiences, which represent, so to speak, the inheritance from untold generations and which are common to all within a given culture. "The collective unconscious, so far as we know, is self-identical in all Western men and thus constitutes a psychic foundation, superpersonal in its nature, that is present in every one of us."

The present volume deals, in rather philosophical style, with individuation and the development of the personality. In this process "let consciousness defend its reason and its self-protective ways, and let the chaotic life of the unconscious be given a fair chance to have its own way, as much of it as we can stand."

In developing his theme, Jung discusses "Archetypes of the Collective Unconscious," "Dream Symbols of the Process of Individuation" (a discussion of a series of dreams of one patient concerning whose history or surroundings no data are given!) and "The Idea of Redemption in Alchemy." There is a wealth of references to Sanskrit art, Coptic and medieval monastic writers, the Gnostic philosophers, and so on, all of which display the erudition of the writer and furnish examples of the recurrence of symbols, in varying times and circumstances.

Chapter 6, "The Development of Personality," becomes a bit more concrete. Jung here makes a plea for the development of adult personalities, pointing out that child-rearing can not best be carried out if the personalities of the adult educators are warped! "Our approach to education suffers from a one-sided emphasis upon the child who is to be brought up, and from an equally one-sided lack of emphasis upon the deficient upbringing of the adult educator."

A personality he defines as "a definitely shaped, psychic abundance, capable of resistance, and endowed with energy." This, he warns us, is an adult ideal, not properly to be foisted upon children. Personality, that is, of the adult, is not manifested "without definiteness, fullness and maturity" (p. 285)—such aims do not fit the child. Some parents, in trying to "do their best" for their children, succeed only in overdoing what has been most neglected in themselves!

Later in the same chapter Jung devotes some space to another kind of "personality," that is, the "historical personality," or what Carlyle would refer to as the "hero." Some few persons, Jung says, learn to liberate themselves from convention, from "the collective fears, convictions, laws and methods" of the mass of mankind (p. 290). This ability he attributes to a "vocation: an irrational factor that fatefully forces a man to emancipate himself from the herd and its trodden paths" (p. 291).

The volume is an interesting production of a great thinker, a thinker with a well-stocked mind but with an irresistible urge to speculate. As one finishes

[1] *The Integration of the Personality.* Carl G. Jung, M.D. Translated by Stanley M. Dell. 313 pp. $3.00. 1939. Farrar and Rinehart.

reading it, he is likely to agree with Jung that, "what is called personality is a great and mysterious question. All that can be said about it is curiously unsatisfactory and inadequate, and there is always the threatening danger that the discussion will lose itself in mere talk that is as redundant as it is hollow."

WINFRED OVERHOLSER, M.D.

## EARLY AMERICANS[1]

IT has been said that, while urban civilized man may or may not have horse sense, primitive preliterate man must have it. Penobscot Man is a record, by the foremost living field worker among our northeastern American Indians, of the manner in which the Penobscot of the Maine woods used their wits to make their living and to survive and thrive as a group. Oddly enough, with all our three or four centuries of white contact with the northeastern Indians, this is our first modern technical monograph on any one group of these forest hunters. It covers all phases of culture—from food to art to society and the life cycle—except religion and folklore.

The data were gathered by Speck chiefly in 1907–14, living and camping with the older men of the tribe. Later visits in 1914–1918 and 1936 helped to fill out the record.

The attempt is not to reconstruct the prehistoric past of the Penobscot, but to present a picture of them as they were in the historic era when native ways and institutions were midway in transition to European forms under French and, later, English influence. A 12-page postscript gives an impressionistic but illuminating sketch of life to-day among the Penobscot. The old era is gone, but not all; beneath the Europeanized surface still lurks no little of the pride of tongue and ancestry, the flair for the hunt, the lure of the rippling waterways, the longing for the deep forest. It is a very human people whom Speck reveals to us, with their loves and their ambitions and their quiet—and often broad—humor. One thumb-nail sketch, that of old Louis Nicholas, is unforgettable, of surpassing pathos, a symbol of the death of a whole culture.

All in all, Penobscot Man is a notable addition to the long list of splendid papers and monographs Speck has given us. It is thoroughly scientific and thoroughly readable. It is crammed with new significant data. The reviewer has no doubt it will take its place among the permanent classics of American Indian ethnology.

JOHN M. COOPER

[1] *Penobscot Man: The Life History of a Forest Tribe in Maine.* Frank G. Speck. Illustrated. xx + 325 pp. $4.00. 1940. University of Pennsylvania Press.

## TOTAL WAR UNDER THE MICROSCOPE[1]

THE most recent addition to the excellent series of Experimental Biology Monographs of the Macmillan Company is a scholarly and original contribution by Valy Menkin on the mechanisms of inflammation. Both the author and the editors of these monographs are deserving of hearty congratulations. The printing and illustrations are worthy of the work. Dr. Menkin briefly and critically reviews earlier theories of the mechanisms and dynamics of inflammation before amplifying his own significant factual and theoretical contributions of the last few years. There is a rare lack of bias in his evaluations of work not in complete accord with his own observations.

The book is highly recommended to those versed in the science of medicine and the related disciplines, but it is rather too technical for the average lay reader.

The author develops an invitingly

[1] *Dynamics of Inflammation. An Inquiry into the Mechanisms of Infectious Processes.* Valy Menkin. Illustrated. xii + 244 pp. $4.50. The Macmillan Company.

logical concept of the dynamics of inflammation in which the role of chemical mediators, such as leukotaxine, is stressed. This theory of pathogenesis of the progressive changes arising in the development of inflammation is, of course, not the final word, but it represents an extremely feasible working hypothesis and should serve to further correlate the facts and ideas concerning cellular reaction to injury. To the suffering individual whose sore finger is the battleground of invading microorganisms, inflammation will mean redness, swelling, heat, pain and tenderness. Dr. Menkin has sought to reveal the intricate machinery, chemical and organic, involved in tissue defense against the invaders: total war under the microscope.

EDWARD J. STIEGLITZ

## MODERN SCIENCE FOR THE AMATEUR[1]

A. FREDERICK COLLINS is called by his publishers "the master hobbyist" because he has written hundreds of articles and scores of popular books, most of them addressed to amateurs and intended to make attractive the actual work of construction and operation in such fields as photography, gardening, aviation, magic, microscopy, wireless, motors and stamp collecting. He has done a tremendous service in this encouragement of the amateur and in this emphasis on the experimental point of view. For not only does science begin with such direct experience, but probably any valid culture for the mass public must be based on the use of the hands, on things to do. All else follows.

[1] *Science on Parade.* A. F. Collins. Illustrated. xi + 314 pp. $3.00. November, 1940. D. Appleton-Century Company.

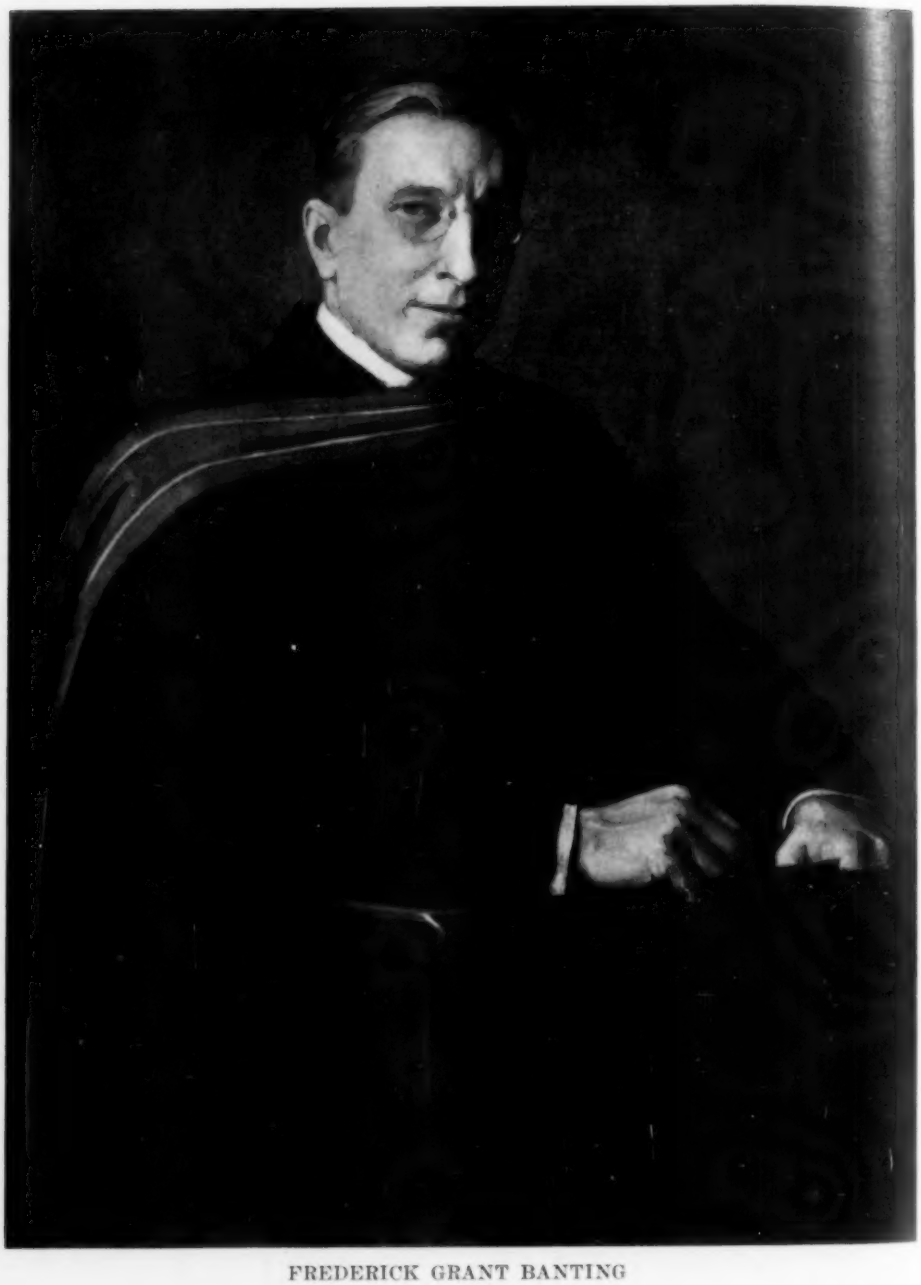
It is therefore interesting to have from him now this book which still maintains primary interest in construction and operation but describes recent advances in industry based on progress in science. These include the Atlantic super-clippers, synthetic materials, artificial lightning, the sterilamp, fluorescent lighting, the electronic piano, color photography, radio facsimile, synthetic speech and television. All these have had ample publicity and are, of course, adequately described in the technical journals, but Mr. Collins's excellent diagrams and clear exposition are the first solid information to amateurs on how they work.

Mr. Collins is at his best in electricity, hence in describing television and facsimile. He is not so specific in the chemical chapters such as synthetic materials and photography, for he assumes less knowledge on the part of his readers. It is, of course, not so easy to be an operating amateur in these chemical matters. Here too he encounters the difficulty of using trade names for the various products and can not be fair to all manufacturers.

Any reviewer must also plead for better titling. The topics discussed do not begin to make a full parade of recent science. Neither can the use of the ultraviolet lamp in sanitation justify the chapter title, "Health on Parade." The fact that the book is otherwise authoritative and precise makes it the more regrettable that the title and chapter headings are vague and grandiose.

This is the kind of book that the amateur needs as an outgrowth of his own more restricted handiwork. It is especially a book that can be recommended for school libraries.

GERALD WENDT



FREDERICK GRANT BANTING

# THE PROGRESS OF SCIENCE

## FREDERICK GRANT BANTING, DISCOVERER OF INSULIN

On February 21st there perished in the wilds of Eastern Newfoundland, as the result of injuries sustained in the crash of a plane England bound, Major Sir Frederick Grant Banting. Thus there came to a tragic end the romantic life of a lovable character and a truly great man. I was perhaps the last of his close friends to see him alive, as we had spent several happy hours together just prior to his departure on his important war-time mission.

Banting was born in Alliston, Ontario, Canada, November 14, 1891, the son of William Thompson Banting and Margaret (Grant) Banting. He was educated at the Alliston public and high schools and at the University of Toronto. He joined the Canadian Army Medical Corps as a private in 1915, and served in Canada, England and France from 1915 to 1919. He was wounded at Cambrai in 1918 and was awarded the Military Cross. After the war he was resident surgeon in the Sick Children's Hospital of Toronto for one year. He practiced medicine in London, Ontario, and held a part-time assistantship in the Department of Physiology in the University of Western Ontario until May, 1921. On May 16 of that year he began work on the problem of the internal secretion of the pancreas in the Department of Physiology of the University of Toronto, under the direction of Professor J. J. R. Macleod. Thereafter, he was lecturer in pharmacology there from 1921 to 1922, senior demonstrator in medicine from 1922 to 1923, and professor of medical research from 1923 until his death. He was honorary consulting physician to the Toronto General Hospital, the Hospital for Sick Children and the Toronto Western Hospital.

He received a degree of doctor of laws from Queen's University in 1923, and doctorates of science from the University of Toronto in 1923, from Yale University in 1924, McGill University in 1939 and, posthumously, from the University of Montreal last March. He was elected a fellow of the Royal Society in 1935.

In June, 1934, Banting was raised to knighthood as a Knight Commander of the Civil Division of the Order of the British Empire. In 1923 he was awarded the Nobel Prize, and in the same year the Parliament of Canada voted him a life annuity.

Banting was a most unselfish individual. He was always mindful of helping others and it was almost a religion with him to encourage, stimulate and assist young research workers. He did not believe that young students should lightly take up research work, but only when they had an impelling urge to do so. Banting's philosophy in regard to this was perhaps never expressed better by him than in the closing paragraphs of his Cameron Prize Lecture to the students of Edinburgh University in 1928.

> The question may arise in the mind of someone present—What may I do? Do not enter upon research unless you can not help it. Ask yourself the "why" of every statement that is made and think out your own answer. If through your thoughtful work you get a worthwhile idea, it will get you. The force of the conviction will compel you to forsake all and seek the relief of your mind in research work. You can prepare yourself for work. The paintings of the great masters, the compositions of great musicians, the sermons of great preachers, the policies of great statesmen, and the campaigns of great generals, do not spring full bloom from barren rock. Your training here is but a preliminary step in preparation for your life work. Mackenzie practiced thirty years before he wrote his book on the heart. Training is required. As Osler says, "live in a day-tight compartment doing each day's work well." If

you are a true student you will be more dissatisfied with yourself when you graduate than you are now. It is not within the power of the properly constructed human mind to be satisfied. Progress would cease if this were the case. The greatest joy in life is to accomplish. It is the getting, not the having. It is the giving, not the keeping.

I am a firm believer in the theory that you can do or be anything that you wish in this world, within reason, if you are prepared to make the sacrifices, think and work hard enough and long enough.

Banting and the writer first met in the early spring of 1921 in the office of Professor J. J. R. Macleod in the Department of Physiology of the University of Toronto, under whom we had both come to work. That day there began a close association between us, and although this was for a time strained by certain misunderstandings, it grew closer with the passing years. I recall quite vividly how impressed I was with Banting and his problem, which was nothing less than a frontal attack on the pancreas to obtain its elusive internal secretion. My own problem, the effect of pH upon the blood sugar, seemed insignificant by comparison, but I had come to work with a man, whereas Banting had a problem which even at that time superseded such things as personalities and graduate training. I feel that I was very fortunate to have been a worker in Macleod's laboratory at the time that Banting started his first investigations and to have known of the progress of this work at first hand. He was most anxious that I should become a co-worker with him. I assured him that I would be delighted to do this, but that I would have to wait until my revered chief, Professor Macleod, said the word. Some weeks later, at a time when Banting's early experiments, in which he had been assisted by C. H. Best (now Professor Best), had in my opinion established completely the existence of insulin, Dr. Macleod asked me to join in the work. The part which I was able to contribute subsequently to the work of the team was only that which any well-trained biochemist could be expected to contribute, and was indeed very trivial by comparison with Banting's contribution.

During the past few years, in connection with the work of the National Research Council of Canada, it has been again my privilege, together with others, to be associated with Banting. The high regard in which he was held by his colleagues in the Research Council, not only on account of his own personality, but for his genius in organization, insight and leadership, can not be expressed better than in the words of the president of the council, Lieutenant-General McNaughton, now heading the Canadian Corps overseas. In a recent tribute to Banting, General McNaughton said in part:

In all our work he gave his best, painstaking help in the administration of the Council's manifold activities, time freely devoted to other sciences as well as medicine, vision and insight and leadership, loyal cooperation and unfailing help and generous encouragement to those who laboured with him in the field of scientific research, modesty almost to a fault. He will be very greatly missed from his place at our Council table. When the dark shadow of war overtook Canada and The Empire he came overseas with the desire for service again with the forces in the field but at my personal request he gave this up unselfishly to undertake the organization of research of far reaching importance to us and which he alone could do. It is in the prosecution of this work that he has given his life.

It is too early for an adequate assessment of Banting's work to be made, but it is certain that at least three of his major accomplishments will long be remembered. These are—the discovery of insulin, the development of the Department of Medical Research of the University of Toronto, which has done and will continue to do notable work of an investigational character, and the initiation, the organization and the carrying-out of research work relating to the war effort.

J. B. Collip

McGill University

## THE NATIONAL GALLERY OF ART[1]

On March 17, President Roosevelt dedicated the new National Gallery of Art at Washington. On the following morning the Gallery, with the Mellon and Kress Collections on view, was opened to the public. The building, under construction for almost four years and recently completed at a cost of fifteen million dollars, was made possible by the gift of the late Andrew W. Mellon. The dedication, on March 17,

[1] The Smithsonian Institution is legally the owner of the National Gallery of Art, including its building and its permanent collections. Title has already passed to it covering the building, and the Mellon and Kress collections. The chancellor of the Board of Regents of the Smithsonian Institution and the secretary of the institution are ex-officio members of the board of nine trustees of the National Gallery. The Smithsonian Institution already owned the Freer Art Gallery, a repository for Oriental Art, and administers the National Collection of Fine Arts and the National Portrait Gallery. Dr. C. G. Abbot, secretary of the Smithsonian Institution, recently expressed the hope that some day a worthy and commodious gallery may be elected for the preservation of the National Collection of Fine Arts, the National Portrait Gallery and the exhibition of contemporary art. Such a gallery will serve not only to receive types of art not within the scope of the National Gallery, but also, as time goes on, to be to some extent its feeder, as contemporary art stands the test of time and itself becomes classic.

"THE ADORATION OF THE SHEPHERDS," BY GIORGIONE

THIS PAINTING, ALSO KNOWN AS THE ALLENDALE ADORATION, IS CONSIDERED TO BE AMONG THE MOST BEAUTIFUL EXAMPLES OF THE ART OF LANDSCAPE DURING THE ITALIAN RENAISSANCE. PART OF THE KRESS COLLECTION, IT IS REPRESENTATIVE OF THE VENETIAN SCHOOL.

THE NEWLY DEDICATED NATIONAL GALLERY OF ART IN WASHINGTON, D. C.

THE BUILDING, CONSTRUCTED OF PINK TENNESSEE MARBLE, LIES IN THE MALL AT A SHORT DISTANCE WEST OF THE UNITED STATES CAPITOL. ITS EXHIBITION AREA AMOUNTS TO ABOUT 238,000 SQUARE FEET. FOUR YEARS WERE REQUIRED FOR ITS CONSTRUCTION.

consummated the plan formulated by Mr. Mellon during the years he spent in Washington as secretary of the treasury, and later announced in a letter to President Roosevelt in December, 1936. In this letter, Mr. Mellon offered to build and to give to the nation an art gallery. He stipulated that the then proposed edifice should not bear his name but should be designated as the "National Gallery of Art." His gift included his collection of paintings and sculpture, which he hoped would become the "nucleus" of a great national collection. The gift was accepted by the Act of Congress of March 24, 1937, and a site for the building extending along Constitution Avenue and the Mall from Fourth to Seventh Streets was provided.

Funds for the maintenance of the gallery, in line with the general practice for the maintenance of other federal museums and art galleries, are to be provided by annual Congressional appropriations.

The architect for the National Gallery of Art was the late John Russell Pope, who died a few weeks after the groundbreaking ceremonies in June, 1937. Pope's associates, Otto B. Eggers and Daniel Paul Higgins, of the firm of Eggers and Higgins of New York City, carried the architectural phase of the construction to its completion.

Conceived as a repository for great masterpieces of art, the gallery is considered by critics to be an outstanding achievement in the field of architectural art.

The pattern of the building consists of two square wings extending from a central rotunda, surrounded by a low dome. Ionic columns supporting broad pediments on the longitudinal faces of the structure, suggest classic Greek influence in architectural design. In general outline the gallery is in harmony with other federal structures along Washington's Constitution Avenue.

In dimensions, the building is 785 feet

THE MAIN ENTRANCE TO THE NATIONAL GALLERY OF ART

THE IONIC COLUMNS SUGGEST CLASSIC GREEK INFLUENCE IN ARCHITECTURAL DESIGN. AMONG THE BUILDINGS VISIBLE FROM THE STEPS ARE THE SMITHSONIAN INSTITUTION, THE U. S. NATIONAL MUSEUM, THE ARMY MEDICAL MUSEUM AND THE U. S. CAPITOL.

long and 305 feet wide. It was erected on a foundation of 6,700 concrete piles. It is constructed principally of hard-surface, rose-white Tennessee marble. Completion of the structure required 800 carloads of this material and represents one of the world's most extensive applications of marble in a single building. The marble in the walls is graduated in color, from strong tones in the lower courses to blend imperceptibly into nearly pure white at the cornice.

The main entrance to the building is through two twelve-ton bronze doors facing Washington's famous Mall. The Mall entrance leads directly to the rotunda, one of the outstanding architectural features of the gallery. The rotunda is one hundred feet in diameter and of equal height. The dome, with its glass-covered oculus, is supported by 24 Ionic columns, carved in Vermont from dark-green Italian marble, quarried in Europe. In the center of the rotunda is a gray marble fountain surmounted by Giovanni Bologna's famous bronze figure of Mercury, from the Mellon Collection, made probably between 1575–1600.

Extending east and west from the rotunda are two large halls or galleries, almost 75 feet wide and more than 100 feet long, which will contain large pieces of sculpture. Already in place in the west hall are two life-size bronze statues of Bacchus and Venus Anadyomene, made about 1525 at Florence by Sansovino. They were once part of Napoleon's National Collection in Paris, acquired by him from northern Italy as "war booty" following his successful campaign against

THE ROTUNDA OF THE NATIONAL GALLERY OF ART

SHOWING A SPECIALLY DESIGNED FOUNTAIN SURMOUNTED BY A BRONZE STATUE OF MERCURY BY GIOVANNI BOLOGNA. THIS STATUE IS ONE OF THE THREE CASTS GENERALLY CONSIDERED TO BE THE ORIGINALS OF THIS FAMOUS REPRESENTATION OF THE MESSENGER OF THE GODS.

Austria. During an uprising in Paris in May, 1871, with the Commune in power, the great Palais Royal was fired by a mob, and the statue of Venus was thrown from a window just in time to prevent its destruction. The scars of this adventure are still visible.

Each of the sculpture halls terminate in a large and beautifully patterend garden court. Seats for the convenience of gallery visitors have been set about the courts in the midst of growing flowers and evergreens. In the center of each court stands one of two well-known fountains which graced the gardens of the palace of Versailles over 250 years ago.

These fountain groups were modeled in lead on the order of Louis XIV between 1670–1675. The fountains are similar in size and general effect and were part of the decorations for the celebrated "Theatre d'Eau" at Versailles. Both are group sculptures; one, by Pierre Legros, represents two winged cherubs playing with a lyre, and the other, by Jean-Baptiste Tubi, depicts two similar figures at play with an irate swan.

The two hundred thousand and more square feet of exhibition area which radiates from the main corridors and garden courts provide space for almost one hundred separate galleries.

The galleries are lighted by natural daylight, diffused through specially treated glass lay-lights. At night or on dark days the paintings and sculpture are illuminated by specially designed floodlights placed above the diffusing glass in the ceilings of the galleries.

"MADONNA AND CHILD," BY ROSSELLINO, MARBLE RELIEF OF THE FLORENTINE SCHOOL WAS EXECUTED BETWEEN 1475 AND 1480.

The Mellon Collection covers the principal European schools from about the year 1200 to the early nineteenth century and includes a number of early American masterpieces. The Kress Collection exhibits Italian painting and sculpture and illustrates the complete development of the Italian schools from the early thirteenth century in Florence, Siena and Rome to the last creative moment in Venice at the end of the eighteenth century.

B. W.

## THE GEOLOGY ALCOVE OF THE SMITHSONIAN'S NEW "INDEX EXHIBIT"

GEOLOGY is the study of the earth. Besides the air (atmosphere) and the oceans (hydrosphere), the earth is thought to consist of a layer of light rock 35 miles thick, a layer of heavy rock 1,000 miles thick, a zone of iron and stone 1,000 miles thick and a central iron core nearly 2,000 miles in diameter. The Smithsonian Institution confines its attention, in the field of geology, largely to the scientific problems of the upper layer of 35 miles. This is perhaps due to its ownership of extensive collections of fossils, minerals, rocks and ores, from this restricted thin

skin of our earth. Since, too, it possesses one of the world's few large meteorite collections, it devotes much attention to these rocks from outer space. The geological display of the new "Index" exhibit is designed to illustrate, in a limited way, the research interests of the Smithsonian.

The central motif of the geological exhibit is a large, slowly rotating globe, with the terrestrial continents, deep buff in color, in relief upon a deep blue sea, signifying in a simple manner that the science of geology concerns itself with the features, both external and internal,

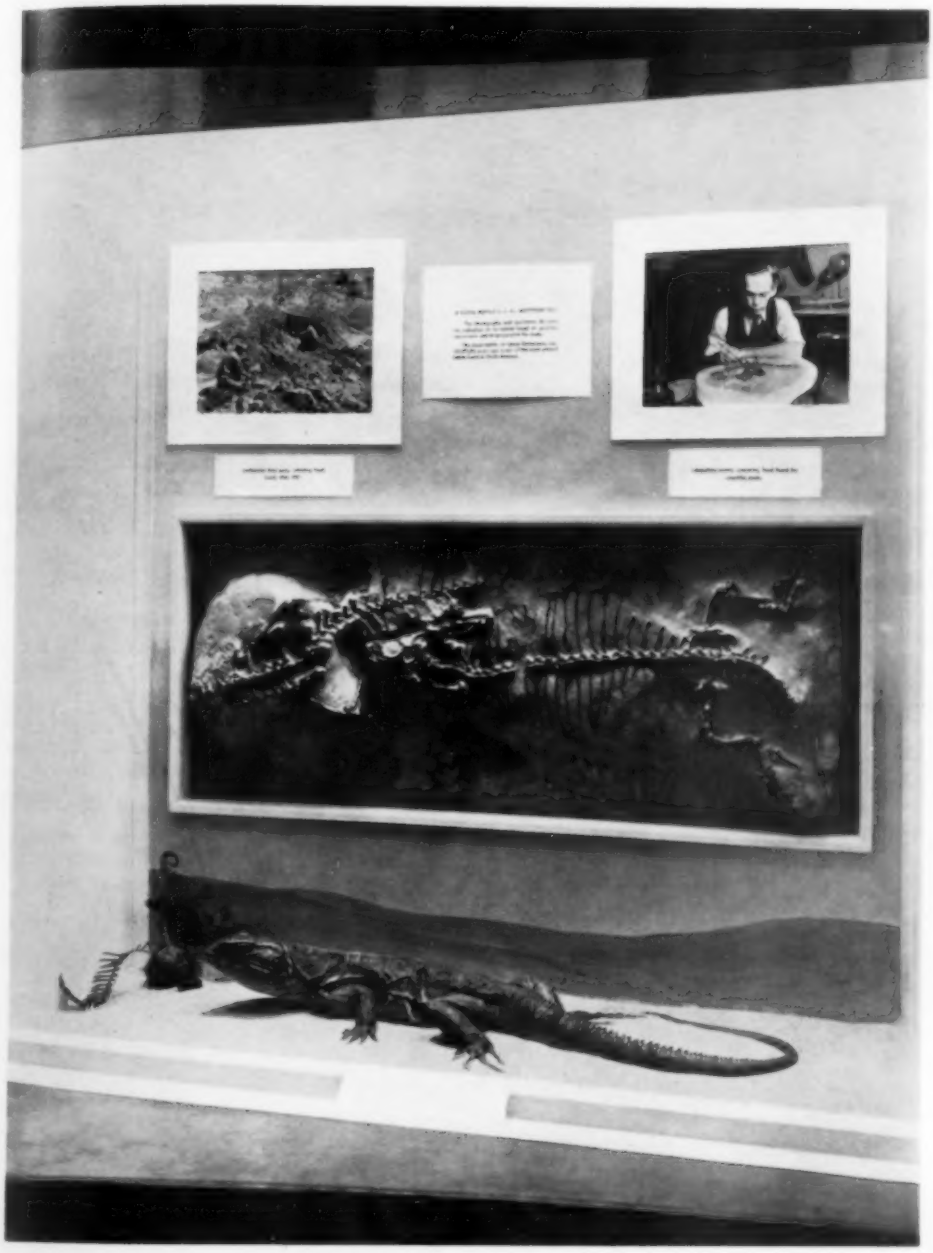
A PORTION OF THE GEOLOGICAL SECTION OF THE SMITHSONIAN'S EXHIBIT

A REVOLVING TERRESTRIAL GLOBE TYPIFIES THE SCIENCE OF GEOLOGY.

of our own planet. Two brief labels explain the constitution of the earth and the Smithsonian's scope of interest. On one side of this central motif are selected exhibits of the Smithsonian's work in paleontology, "the study of fossil animals and plants," and on the other, some phases of its interest in mineralogy, "the study of minerals."

Down the center of the paleontology section is a column of three small dioramas, showing characteristic scenes from three ancient geological eras: for the Cenozoic, a three-toed horse and a primitive carnivore against a background of flowering trees; for the Mesozoic, an armored dinosaur against palms and cycads; and for the Paleozoic, the struggle for existence between trilobites and cephalopods in an ancient sea. One panel shows, as an example, the activities of the vertebrate paleontologists, work both in the field and in the laboratory on an extinct lizard from the Cretaceous epoch, 100,000,000 years ago, one of the most ancient lizards found in North America. This includes a block of rock with two articulated skeletons worked out in relief, and a restoration of the lizard based upon the scientific study of these and other skeletons found associated with them. The other panel illustrates some researches in Permian invertebrate paleontology, with blocks of fossil-bearing limestone, both as found in the field and as partially prepared in the laboratory; and the remains of fossil animals, bryozoans, brachiopods, molluscans and other forms, with their delicate features preserved in silica for 200,000,000 years. Studies on these forms increase our knowledge of the history of life during this remote period.

On the other side, relating to mineralogy in its broadest sense, is a long panel showing by an illuminated scene a meteorite in flight, and characteristic indi-



THE STUDY OF A FOSSIL LIZARD

PHOTOGRAPHS SHOW A SMITHSONIAN EXPEDITION IN THE FIELD AND LATER WORK IN THE LABORATORY. BELOW THESE ARE A PREPARED SKELETON AND A RESTORATION OF THE LIZARD.

SOME MINERALS FROM THE PRINCE OF WALES ISLAND, ALASKA

AGAINST A PAINTED BACKGROUND OF THE LOCALITY ARE ARRANGED SOME OF THE MATERIALS COLLECTED DURING A SMITHSONIAN EXPEDITION.

viduals of the three main types of these strange visitors from outer space: the stony, stony-iron and iron meteorites. Below is a panel of crystallized minerals from Prince of Wales Island, Alaska; epidote, garnet and others against a painted background of the locality and a small "telescope" in which one can view the work of collecting these minerals on the distant mountain slope. The specimens were selected, not only to show the character of material with which the mineralogist works, but the beauty of the mineral kingdom as well. A second case shows typical silver-lead and silver-gold ores from Mexico and some of the minerals in well-crystallized groups, that are commonly found in these ores. This exhibit illustrates the economic mineralogy of the rich mineral regions of Mexico, in which the Smithsonian has long been interested. Finally, a small recessed case shows a brilliant cut gem of topaz gleaming in a dimly lighted recess and a topaz crystal of the same material, both from the gem mines of Brazil.

Each year the Smithsonian conducts geological explorations and researches in various parts of the world. These exhibits illustrate some of them.

W. F. FOSHAG
SMITHSONIAN INSTITUTION

## PALEONTOLOGICAL EXPEDITION INTO THE SOUTH DAKOTA BADLANDS

A COLLECTION of more than 175 fossil specimens made last summer in the South Dakota Badlands by a joint paleontological expedition of the National Geographic Society and the South Dakota State School of Mines is undergoing study. Preliminary investigations in the workrooms of the Museum of the School of Mines indicate that many of the fossils are rare and that several represent species and genera new to science. It is believed probable that the two most strik-

A FERTILE HUNTING GROUND

IN SUCH ERODED AREAS OF THE WHITE RIVER BADLANDS, SOUTH DAKOTA, THE EXPEDITION FOUND MORE THAN 175 SPECIMENS OF FOSSIL BONES OF MAMMALS, BIRDS AND REPTILES. THE CAPSTONES ARE OF CHANNEL SANDSTONE OVERLYING SHALES.

CAMP OF THE PALEONTOLOGICAL EXPEDITION IN THE WHITE RIVER BADLANDS

ing specimens found will fall into the latter group: a rhinoceros skull 28 inches long, and the skull of a giant pig which measured, when alive, fully eight feet from snout to tail.

Among other specimens found by the expedition were fossil bones of tapirs, graceful little three-toed horses (the remote ancestors of present-day horses), protoceros (remotely related to deer and antelope), the little-known ancodus and a number of small rodents. Rarest of the specimens are bones of birds—only a few have previously been found in the Badlands. The prize find, which may belong in this group or which may be of reptilian origin, was a fossil egg still firmly held in its matrix of rock. A few plant fossils were found: fossil hackberry seeds and petrified hackberry wood.

Led by Dr. Joseph P. Connolly, president of the School of Mines, and James D. Bump, curator of the museum, the expedition, including seven other members, established camp in a fantastically eroded region 25 miles from the nearest highway. Their work was carried on in the summer sunshine, where mid-afternoon temperatures frequently reached 120 and 130 degrees Fahrenheit. Some of the heaviest specimens were found near the tops of high, slender pinnacles and had to be lowered by block-and-tackle.

The material collected by the expedition is particularly rich in rare specimens because the work was confined to geological formations in which very little work has been done heretofore. These are the Channel Sandstones, so called because the beds were formed by deposits filling stream channels worn in the clay surfaces in Oligocene times, probably 30 million years ago. The surrounding clay—now turned to shale—is softer and much more easily worked, and from it have come most of the Badlands specimens previously collected.

In the museum workrooms at the School of Mines, the specimens are being placed one after another on the "operating table." Each is protected by many yards of bandages which were soaked in a plaster of paris "soup." These bandages were allowed to stiffen before removal from the field, and furnished ideal protecting shells for the specimens. In the workrooms the bandages are first cut away, and the rocky matrix, which still partly envelops the specimens, is carefully removed with chisels, dentists' tools and scrapers. As areas of the fossil bone are exposed they are impregnated with a thin solution of shellac to harden them.

M. F.

## THE PAPER-MAKING MACHINE AT THE FRANKLIN INSTITUTE

PAPER has become a vital necessity in our daily lives. Without it, printing would be almost valueless, knowledge would be obscure, and countless industries would be at a standstill.

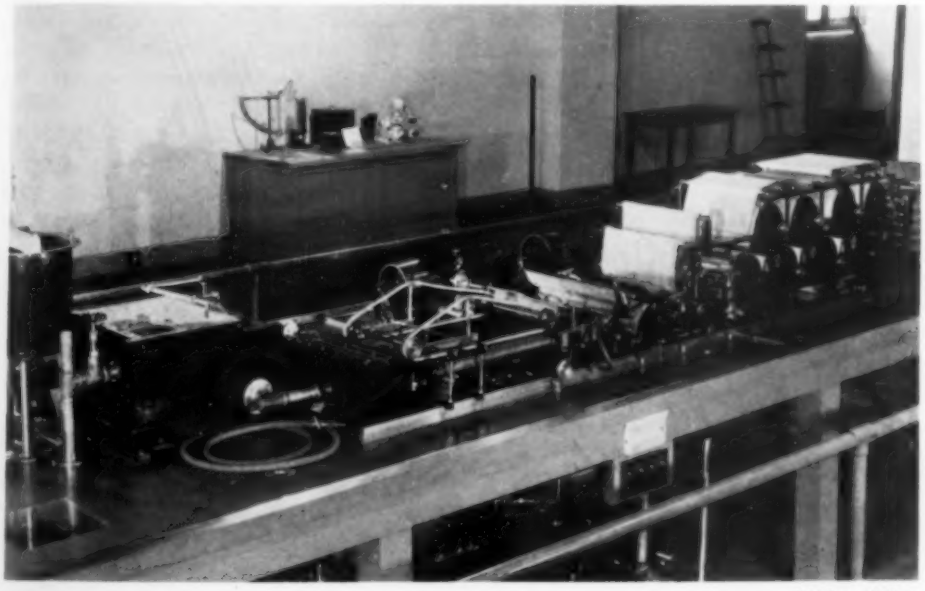
There are many people using it every day and depending on it for a livelihood who have never visited a factory or given a thought to how it is made. They have never watched the tremendous speed of the gigantic machines as they turn it out—a thousand feet a minute—two tons in a single day.

For those who know nothing about the processes of paper-making and do not live near a mill, the Franklin Institute in Philadelphia has on permanent exhibition a scale model paper-making machine of the Fourdrinier type. It is the only one of its kind in the world, and demonstrates to the visitors how paper is made in an easy understandable way, without even the confusion one might find in a large factory where just one of the thirty dryers is taller than the average man. This useful model is so small that all the stages of paper-making can be seen in a glance, and yet so large that each individual procedure can be carefully examined.

*Gladys Müller*

AN EXPERIENCED PAPER-MAKER DEMONSTRATING THE MACHINE TO FRANKLIN INSTITUTE VISITORS

Placed on a steel table eighteen feet long and four and one half feet wide, the machine makes five feet of paper a minute, eight and one quarter inches wide and can produce three or four pounds an hour. It is operated and controlled by push buttons and powered by variable speed electric motors. A mixture of wood pulp, soda and sulfite is used in the small beater, and the machine



*Gladys Müller*

SCALE MODEL FOURDRINIER PAPER-MAKING MACHINE

is complete with a motor-driven pump, miniature dryers and press felts.

Until the early part of the nineteenth century, paper had been made almost entirely by hand, but at that time a Frenchman, Louis Robert, and several other men were granted patents for paper-making machines. Shortly afterwards the invention was taken to England, where a new company, backed by two English stationers, Henry and Seeley Fourdrinier, began building machines in 1807 which were sent to other parts of the world bearing the name of the financiers.

In 1816, John Gilpin, of Philadelphia, took out patents for the first American paper machine, and examples of the paper he made on it were displayed at the opening exhibition of the Franklin Institute. Ten years later, Allen and William Curtis were operating two Fourdrinier machines, which they had purchased in England, at their mill on the Charles River.

Since those early days, the United States has taken the lead in the manufacture of paper, and now, just 250 years after David Rittenhouse started the first mill near Philadelphia, this country produces more paper than the rest of the world combined. EMILY D. WALLACE

## BOMBPROOF SHELTERS

NEARLY a year ago the American public was thrilled at the president's blithe reference to our producing 50,000 military airplanes per year and at Mr. Ford's alleged statement that he could manufacture 1,000 a day. Now bombproof shelters are called for with similar disregard for serious difficulties.

For a structure to be really bombproof its cover and sides must be of five to ten feet of reinforced concrete or its equivalent. It must be proof against poison gas from the outside, and it must have unfailing facilities for ventilation. It must have an unfailing lighting system, it must have water and sanitary conveniences with unfailing drainage to avoid drowning in case water pipes are broken, it must have a first aid station, it must have separate sleeping rooms for men and women, it must have telephone communication with the outside, it must have more than one exit, etc.

What about the cost of bombproof structures? For those that are really bombproof the cost has been estimated to be of the order of $100 per person, or about $66,000,000 for such a city as Washington. The enormous cost in money is only a minor part of the problem of providing bombproof shelters for our great cities. The diversion of skilled labor in their construction and the drain on materials essential for other purposes would disrupt any adequate defense program. If our forests were not so depleted we might take to the woods.

F. R. M.

## ZWICKY'S SYSTEMS IN SEXTANS AND IN LEO

THE SCIENTIFIC MONTHLY for November, 1940, contains an article entitled "Problems of Nebular Research" written by me and illustrated by Mount Wilson photographs. Two unusually interesting dwarf irregular nebulae, shown on plates facing pages 399 and 401, are called "Baade's System in Sextans" and "Baade's System in Leo," respectively.

These designations are incorrect. They should be "Zwicky's System in Sextans" and "Zwicky's System in Leo." Both nebulae were discovered by Dr. Fritz Zwicky, of the California Institute of Technology, who identified them on photographs with the 18-inch Schmidt reflector, as objects which fulfilled his criteria for dwarf systems of the type in question.

Dr. Zwicky assembled a list of such objects for further investigation with large telescopes. Dr. Baade, with the 100-inch, verified the identification of the two systems under discussion and at the same time determined their distances.

The matter of nomenclature is important because these dwarf systems may play a significant rôle in cosmological theory. The regrettable error was called to my attention by Dr. Baade and Dr. Zwicky. EDWIN HUBBLE